US010653425B1

(12) **United States Patent**
Gorochow et al.

(10) **Patent No.: US 10,653,425 B1**
(45) **Date of Patent: May 19, 2020**

(54) **LAYERED BRAIDED ANEURYSM TREATMENT DEVICE**

(71) Applicant: **DePuy Synthes Products, Inc.**, Raynham, MA (US)

(72) Inventors: **Lacey Gorochow**, Raynham, MA (US); **Ariel Soto Del Valle**, Raynham, MA (US)

(73) Assignee: **DePuy Synthes Products, Inc.**, Raynham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/418,199**

(22) Filed: **May 21, 2019**

(51) **Int. Cl.**
A61B 17/12 (2006.01)

(52) **U.S. Cl.**
CPC .. ***A61B 17/12113*** (2013.01); ***A61B 17/12031*** (2013.01); ***A61B 17/12168*** (2013.01); *A61B 2017/12054* (2013.01)

(58) **Field of Classification Search**
CPC A61B 17/12022; A61B 17/12031; A61B 17/12109; A61B 17/12113; A61B 17/1214; A61B 17/12145; A61B 17/12168; A61B 17/12172
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,391,037	B1	5/2002	Greenhalgh
6,506,204	B2	1/2003	Mazzocchi et al.
8,777,974	B2	7/2014	Amplatz et al.
8,974,512	B2	3/2015	Aboytes et al.
8,998,947	B2	4/2015	Aboytes et al.
9,055,948	B2	6/2015	Jaeger et al.
9,232,992	B2	1/2016	Heidner
9,314,326	B2	4/2016	Wallace et al.
9,532,792	B2	1/2017	Galdonik et al.
9,532,873	B2	1/2017	Kelley
9,533,344	B2	1/2017	Monetti et al.
9,539,011	B2	1/2017	Chen et al.
9,539,022	B2	1/2017	Bowman
9,539,122	B2	1/2017	Burke et al.
9,539,382	B2	1/2017	Nelson

(Continued)

FOREIGN PATENT DOCUMENTS

JP	2016-502925	A	2/2016
WO	2005/117718	A1	12/2005
WO	2015/160721	A1	10/2015
WO	2015/171268	A2	11/2015

OTHER PUBLICATIONS

File History for corresponding U.S. Appl. No. 15/430,141, filed Feb. 10, 2017.

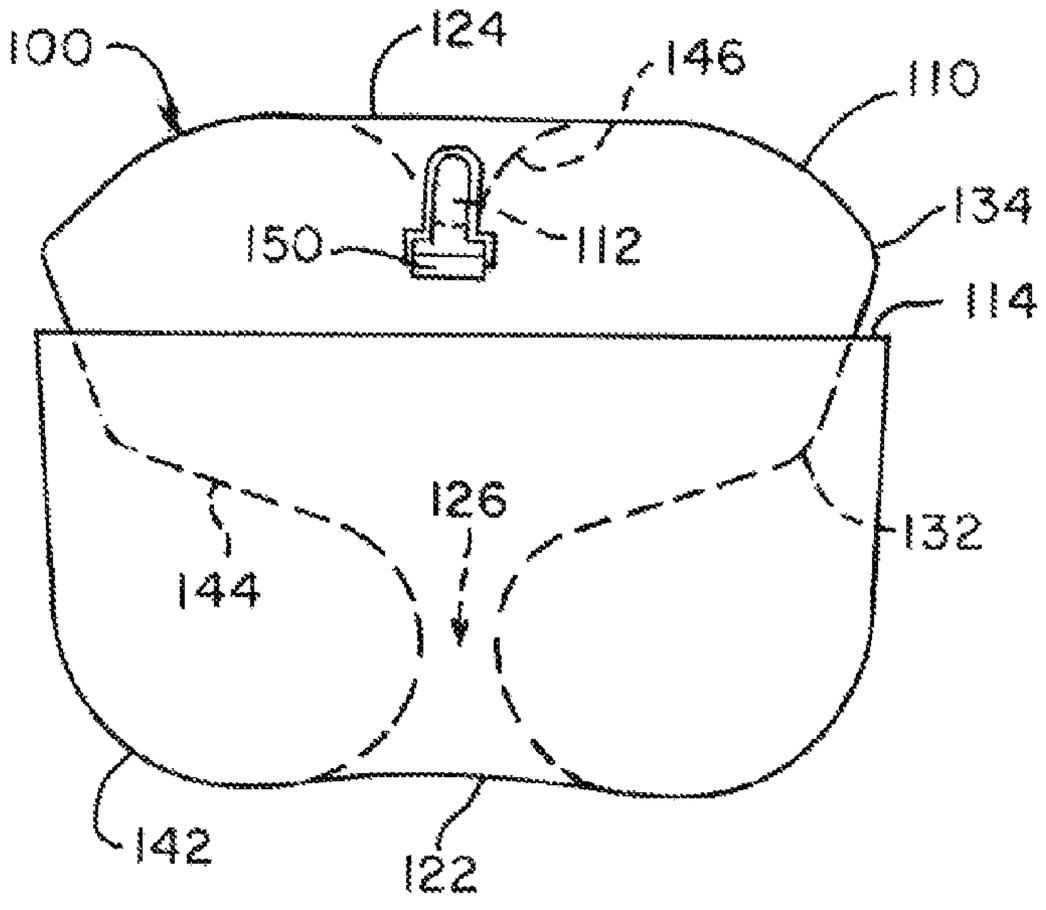
(Continued)

Primary Examiner — Todd J Scherbel
(74) *Attorney, Agent, or Firm* — Troutman Sanders LLP

(57) **ABSTRACT**

A braided implant is provided that can secure within an aneurysm sac, occlude a majority of the aneurysm's neck, and at least partially fill the aneurysm sac. The implant can include a tubular braid that can be set into a predetermined shape, compressed for delivery through a microcatheter, and implanted in at least one implanted position. In some examples, the tubular braid can be implanted in two distinct implanted shapes, allowing for treatment of a wide range of aneurysm sizes. In some examples, the implanted braid can include a compaction resistant column spanning the height of the aneurysm.

9 Claims, 15 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

9,549,830	B2	1/2017	Bruszewski et al.	
9,554,805	B2	1/2017	Tompkins et al.	
9,561,125	B2	2/2017	Bowman et al.	
9,572,982	B2	2/2017	Burnes et al.	
9,579,484	B2	2/2017	Barnell	
9,585,642	B2	3/2017	Dinsmoor et al.	
9,615,832	B2	4/2017	Bose et al.	
9,615,951	B2	4/2017	Bennett et al.	
9,622,753	B2	4/2017	Cox	
9,636,115	B2	5/2017	Henry et al.	
9,636,439	B2	5/2017	Chu et al.	
9,642,675	B2	5/2017	Werneth et al.	
9,655,633	B2	5/2017	Leynov et al.	
9,655,645	B2	5/2017	Staunton	
9,655,989	B2	5/2017	Cruise et al.	
9,662,129	B2	5/2017	Galdonik et al.	
9,662,238	B2	5/2017	Dwork et al.	
9,662,425	B2	5/2017	Lilja et al.	
9,668,898	B2	6/2017	Wong	
9,675,477	B2	6/2017	Thompson	
9,675,782	B2	6/2017	Connolly	
9,676,022	B2	6/2017	Ensign	
9,692,557	B2	6/2017	Murphy	
9,693,852	B2	7/2017	Lam et al.	
9,700,262	B2	7/2017	Janik et al.	
9,700,399	B2	7/2017	Acosta-Acevedo	
9,717,421	B2	8/2017	Griswold et al.	
9,717,500	B2	8/2017	Tieu et al.	
9,717,502	B2	8/2017	Teoh et al.	
9,724,103	B2	8/2017	Cruise et al.	
9,724,526	B2	8/2017	Strother et al.	
9,750,565	B2	9/2017	Bloom et al.	
9,757,260	B2	9/2017	Greenan	
9,764,111	B2	9/2017	Gulachenski	
9,770,251	B2	9/2017	Bowman	
9,770,577	B2	9/2017	Li	
9,775,621	B2	10/2017	Tompkins et al.	
9,775,706	B2	10/2017	Paterson	
9,775,732	B2	10/2017	Khenansho	
9,788,800	B2	10/2017	Mayoras, Jr.	
9,795,391	B2	10/2017	Saatchi et al.	
9,801,980	B2	10/2017	Karino et al.	
9,808,599	B2	11/2017	Bowman	
9,833,252	B2	12/2017	Sepetka	
9,833,604	B2	12/2017	Lam	
9,833,625	B2	12/2017	Waldhauser et al.	
2003/0171739	A1	9/2003	Murphy et al.	
2003/0195553	A1	10/2003	Wallace et al.	
2005/0251200	A1	11/2005	Porter	
2006/0052816	A1	3/2006	Bates et al.	
2006/0064151	A1	3/2006	Guterman	
2008/0281350	A1	11/2008	Sepetka	
2010/0023046	A1	1/2010	Heidner et al.	
2010/0023048	A1*	1/2010	Mach	A61B 17/0057 606/200
2010/0324649	A1	12/2010	Mattsson	
2011/0152993	A1	6/2011	Marchand et al.	
2012/0283768	A1	11/2012	Cox et al.	
2013/0204351	A1	8/2013	Cox et al.	
2014/0135812	A1	5/2014	Divino et al.	
2014/0200607	A1	7/2014	Sepetka et al.	
2015/0209050	A1	7/2015	Aboytes et al.	
2015/0272589	A1	10/2015	Lorenzo	
2015/0342613	A1	12/2015	Aboytes et al.	
2015/0374483	A1	12/2015	Janardhan et al.	
2016/0022445	A1	1/2016	Ruvalcaba et al.	
2016/0249934	A1	9/2016	Hewitt et al.	
2017/0007264	A1	1/2017	Cruise et al.	
2017/0007265	A1	1/2017	Guo et al.	
2017/0020670	A1	1/2017	Murray et al.	
2017/0020700	A1	1/2017	Bienvenu	
2017/0027640	A1	2/2017	Kunis et al.	
2017/0027692	A1	2/2017	Bonhoeffer	
2017/0027725	A1	2/2017	Argentine	
2017/0035436	A1	2/2017	Morita	
2017/0035567	A1	2/2017	Duffy	
2017/0042548	A1	2/2017	Lam	
2017/0049596	A1	2/2017	Schabert	
2017/0071737	A1	3/2017	Kelley	
2017/0072452	A1	3/2017	Monetti et al.	
2017/0079671	A1	3/2017	Morero	
2017/0079680	A1	3/2017	Bowman	
2017/0079766	A1	3/2017	Wang	
2017/0079767	A1	3/2017	Leon-Yip	
2017/0079812	A1	3/2017	Lam et al.	
2017/0079817	A1	3/2017	Sepetka	
2017/0079819	A1	3/2017	Pung et al.	
2017/0079820	A1	3/2017	Lam et al.	
2017/0086851	A1	3/2017	Wallace	
2017/0086996	A1	3/2017	Peterson et al.	
2017/0095259	A1	4/2017	Tompkins et al.	
2017/0100126	A1	4/2017	Bowman et al.	
2017/0100141	A1	4/2017	Morero et al.	
2017/0100143	A1	4/2017	Granfield	
2017/0100183	A1	4/2017	Iaizzo	
2017/0113023	A1	4/2017	Steingisser et al.	
2017/0147765	A1	5/2017	Mehta	
2017/0151032	A1	6/2017	Loisel	
2017/0165062	A1	6/2017	Rothstein	
2017/0165065	A1	6/2017	Rothstein	
2017/0165454	A1	6/2017	Tuohy	
2017/0172581	A1	6/2017	Bose et al.	
2017/0172766	A1	6/2017	Vong et al.	
2017/0172772	A1	6/2017	Khenansho	
2017/0189033	A1	7/2017	Sepetka et al.	
2017/0189035	A1	7/2017	Porter	
2017/0215902	A1	8/2017	Leynov et al.	
2017/0216484	A1	8/2017	Cruise et al.	
2017/0224350	A1	8/2017	Shimizu et al.	
2017/0224355	A1	8/2017	Bowman et al.	
2017/0224467	A1	8/2017	Piccagli et al.	
2017/0224511	A1	8/2017	Dwork et al.	
2017/0224953	A1	8/2017	Tran et al.	
2017/0231749	A1	8/2017	Perkins et al.	
2017/0252064	A1	9/2017	Staunton	
2017/0265983	A1	9/2017	Lam et al.	
2017/0281192	A1	10/2017	Tieu et al.	
2017/0281331	A1	10/2017	Perkins et al.	
2017/0281344	A1	10/2017	Costello	
2017/0281909	A1	10/2017	Northrop et al.	
2017/0281912	A1	10/2017	Melder	
2017/0290593	A1	10/2017	Cruise et al.	
2017/0290654	A1	10/2017	Sethna	
2017/0296324	A1	10/2017	Argentine	
2017/0296325	A1	10/2017	Marrocco et al.	
2017/0303939	A1	10/2017	Greenhalgh	
2017/0303942	A1	10/2017	Greenhalgh et al.	
2017/0303947	A1	10/2017	Greenhalgh	
2017/0303948	A1	10/2017	Wallace et al.	
2017/0304041	A1	10/2017	Argentine	
2017/0304097	A1	10/2017	Corwin et al.	
2017/0304595	A1	10/2017	Nagasrinivasa	
2017/0312109	A1	11/2017	Le	
2017/0312484	A1	11/2017	Shipley et al.	
2017/0316561	A1	11/2017	Helm et al.	
2017/0319826	A1	11/2017	Bowman	
2017/0333228	A1	11/2017	Orth et al.	
2017/0333236	A1	11/2017	Greenan	
2017/0333678	A1	11/2017	Bowman	
2017/0340383	A1	11/2017	Bloom et al.	
2017/0348014	A1	12/2017	Wallace	
2017/0348514	A1	12/2017	Guyon et al.	
2018/0242979	A1	8/2018	Lorenzo	
2019/0365385	A1*	12/2019	Gorochow	A61B 17/12168

OTHER PUBLICATIONS

File History for corresponding U.S. Appl. No. 15/430,419, filed Feb. 10, 2017.

File History for corresponding U.S. Appl. No. 62/293,710, filed Feb. 10, 2017.

* cited by examiner

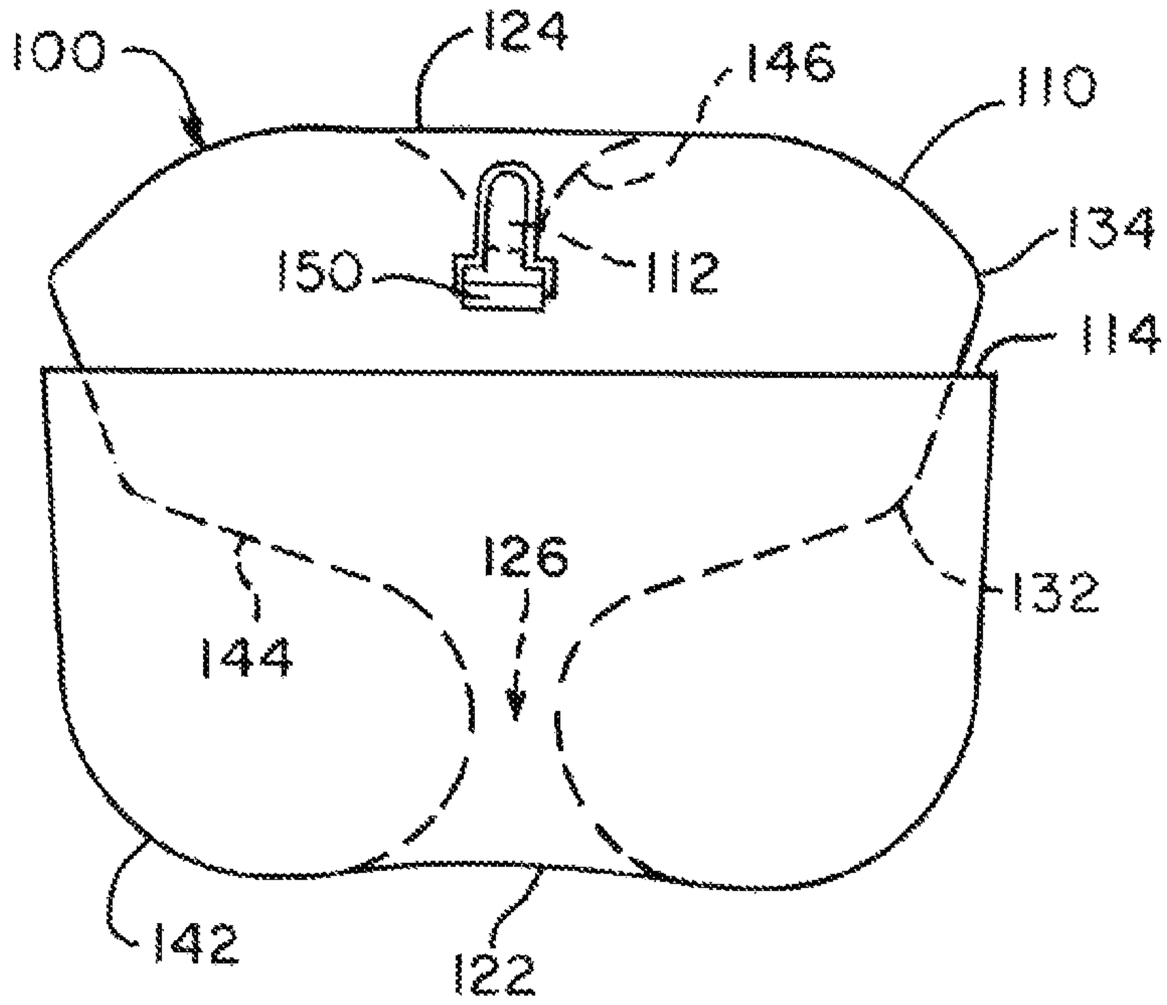

100
124
146
110
134
150
112
114
126
132
144
142
122

FIG. 1A

FIG. 1B

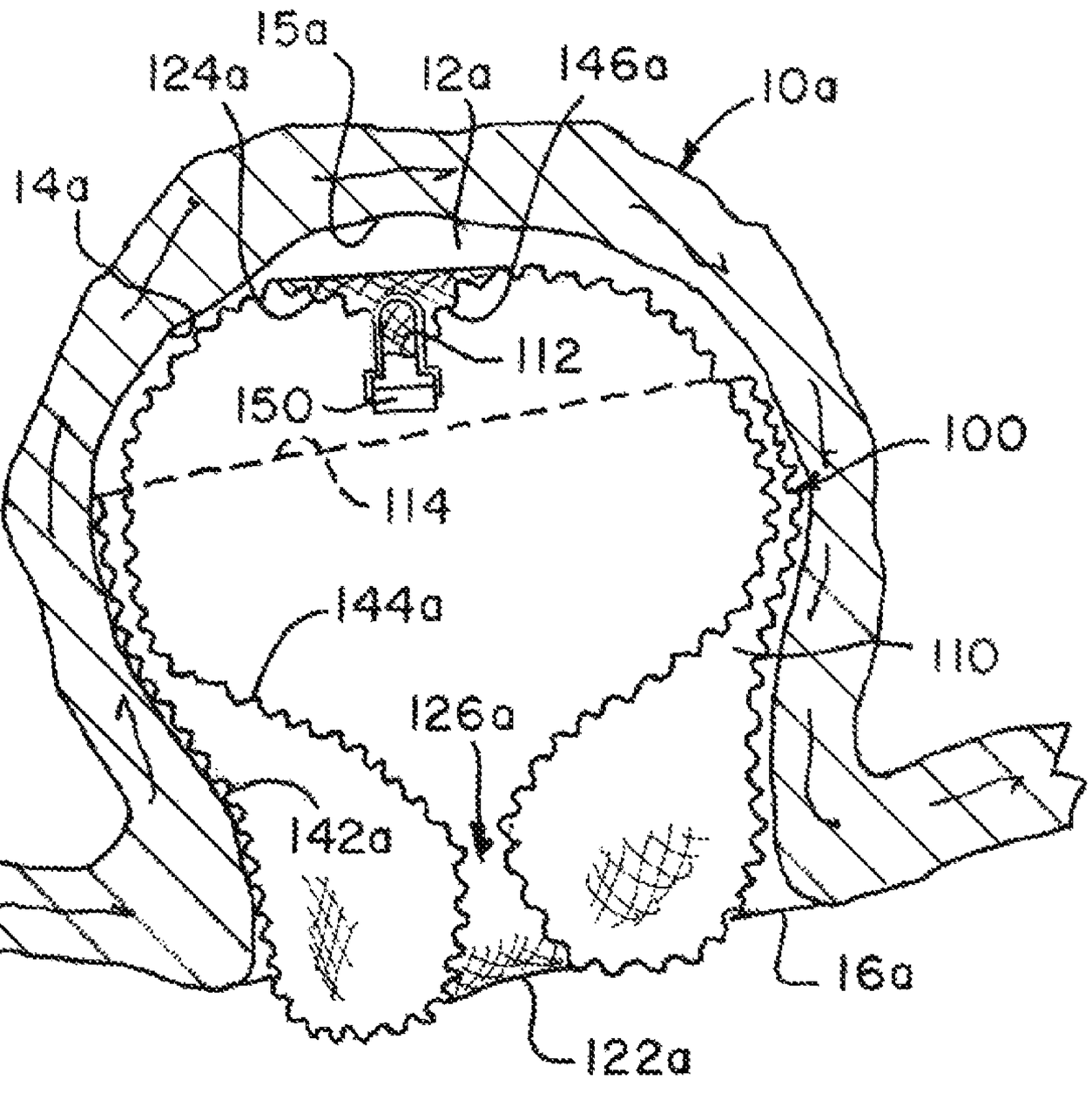

15a
124a
12a
146a
10a
14a
112
150
100
114
144a
110
126a
142a
16a
122a

FIG. 1C

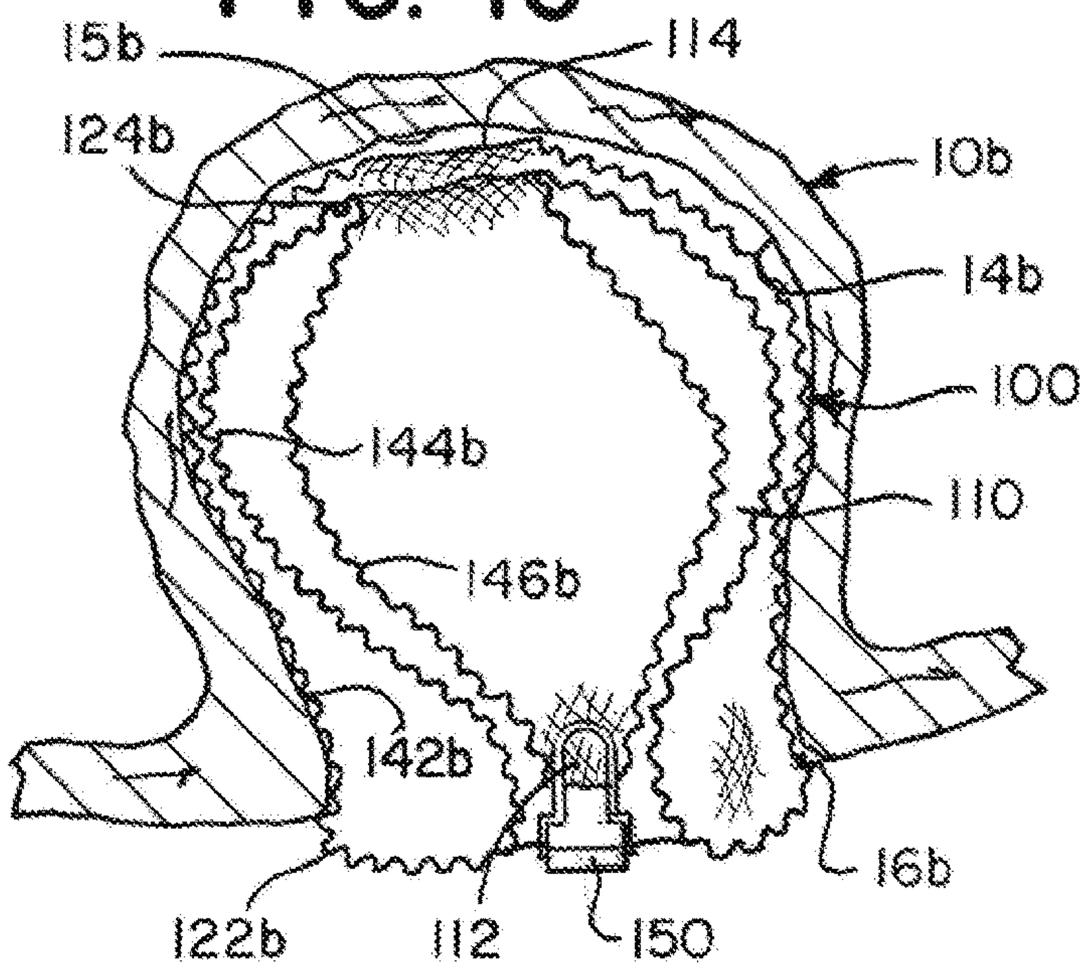
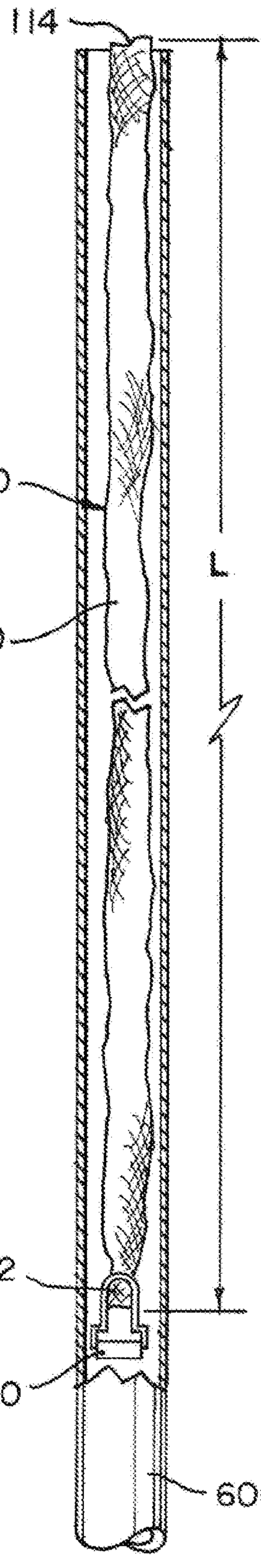


FIG. 2A



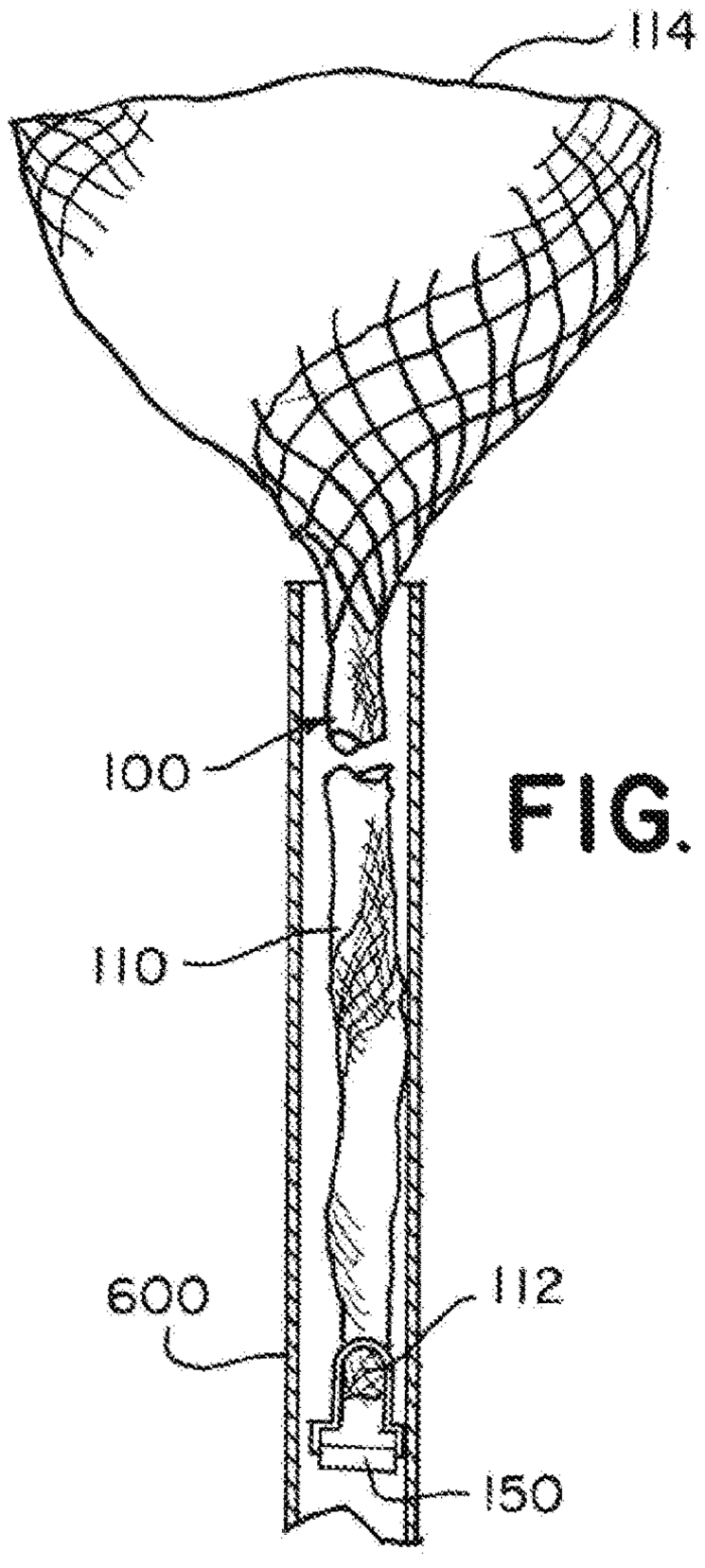


FIG. 2B

FIG. 2C

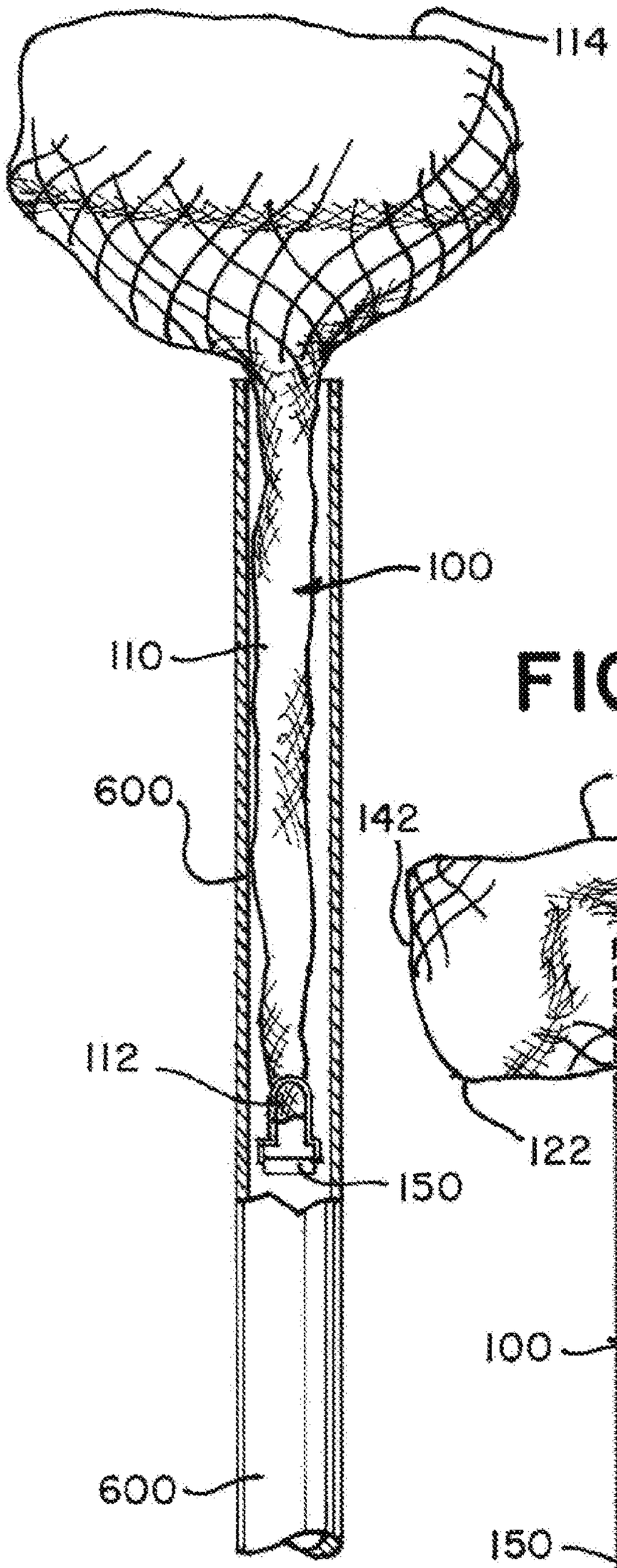


FIG. 2D

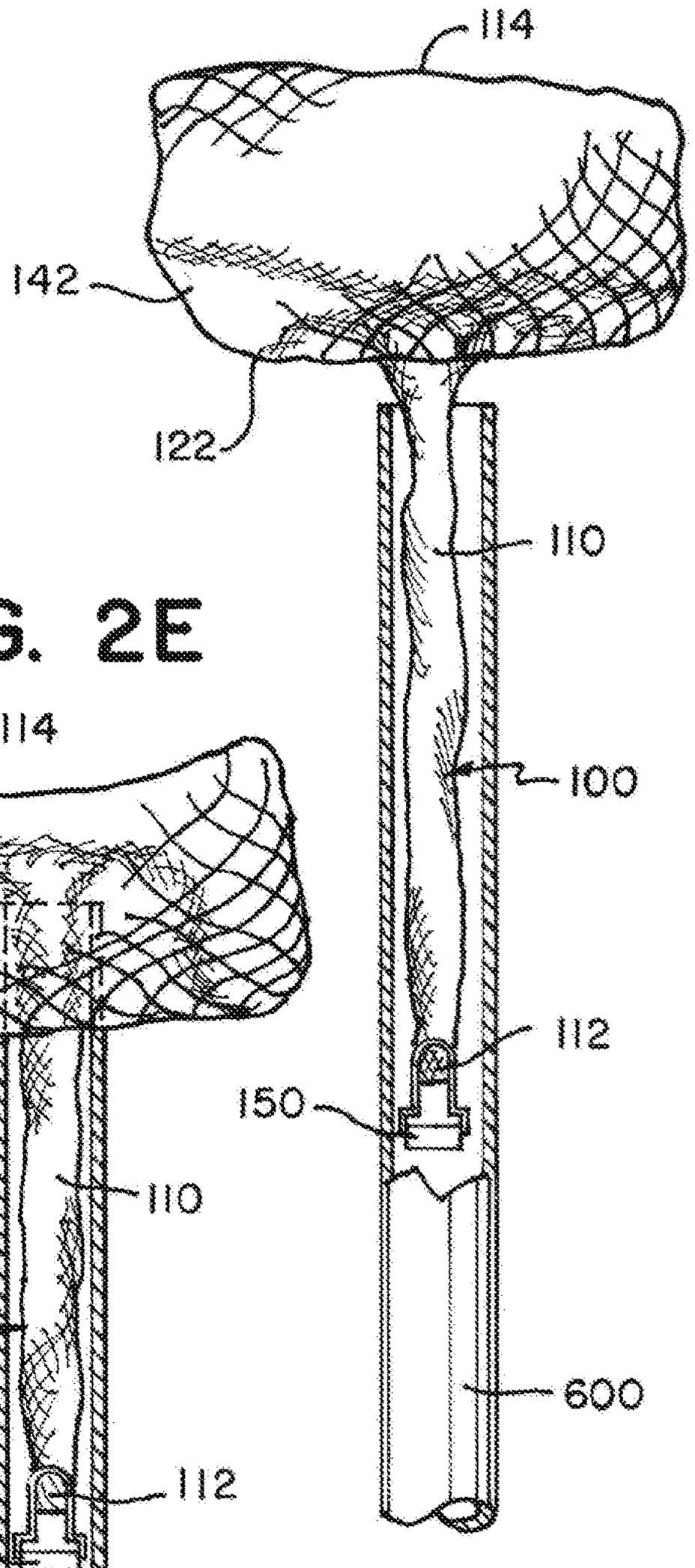


FIG. 2E

FIG. 2F

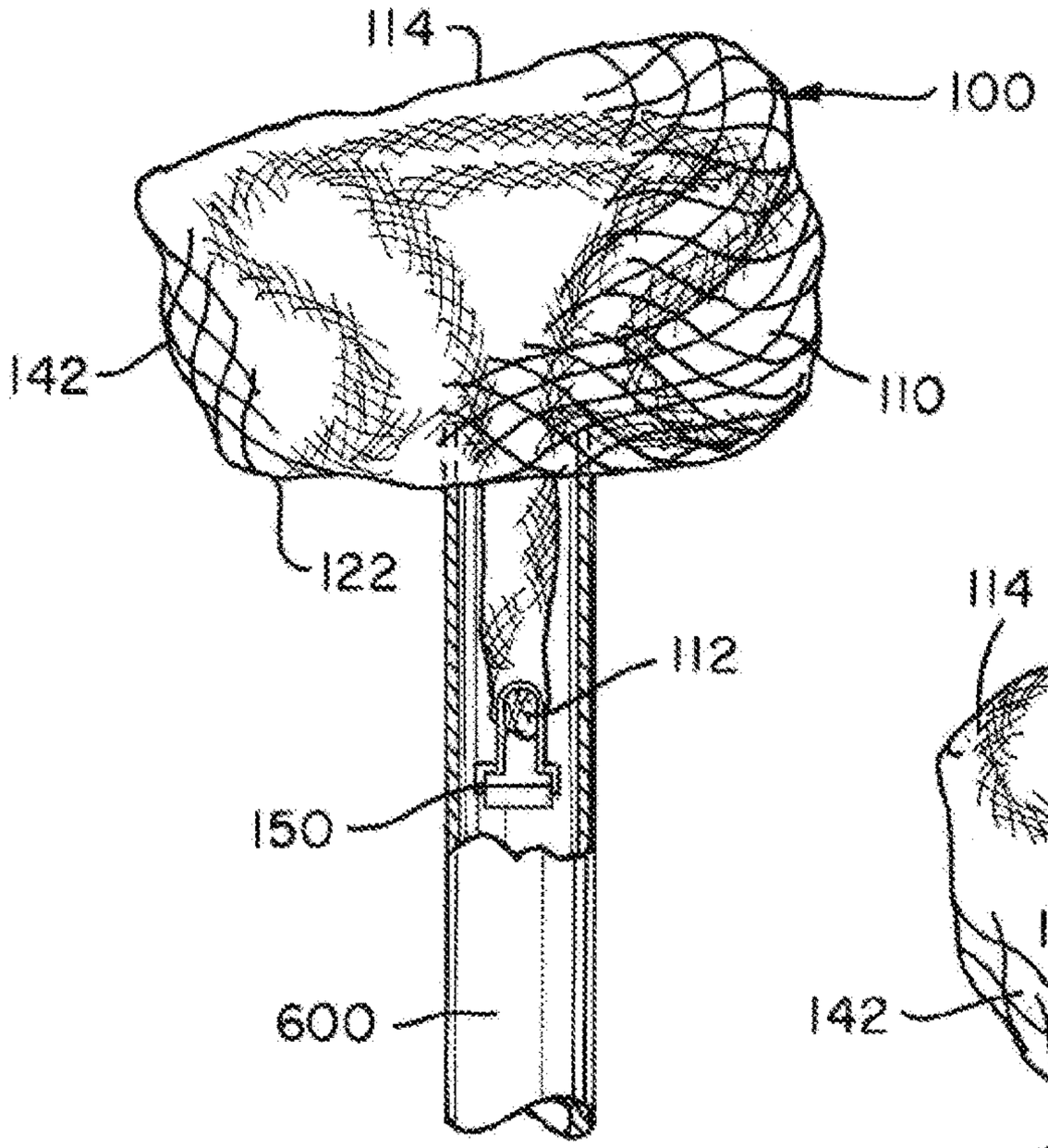


FIG. 2G

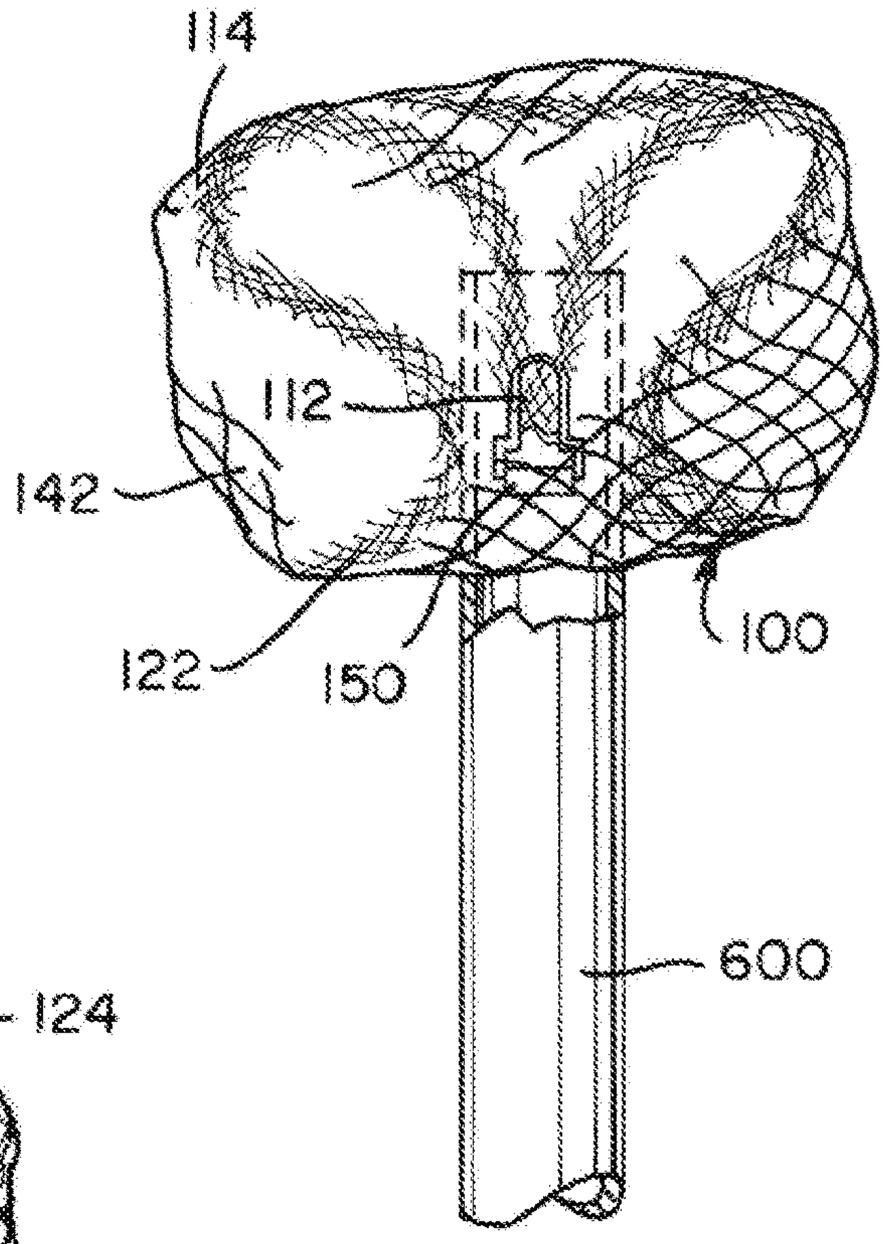


FIG. 2H

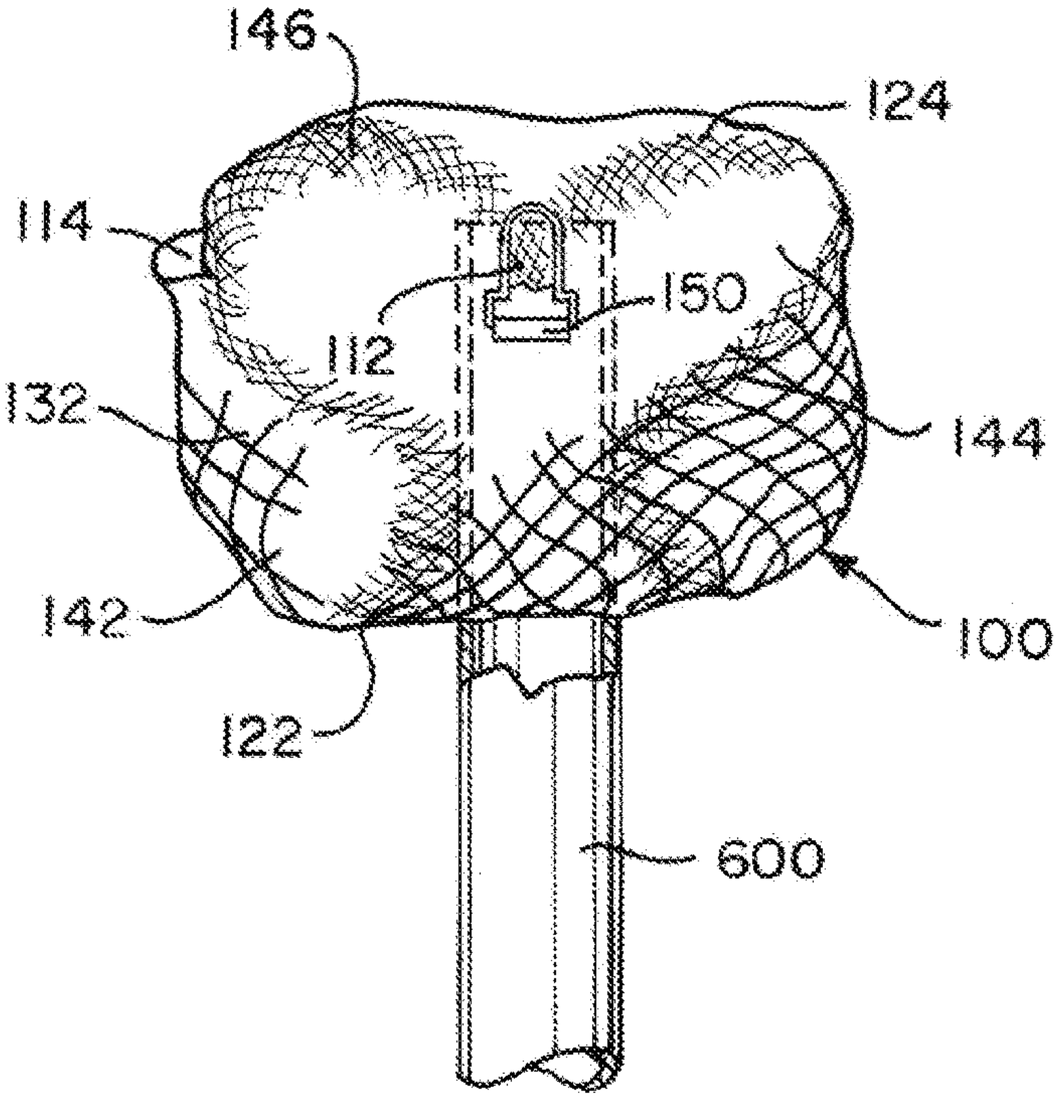


FIG. 3B

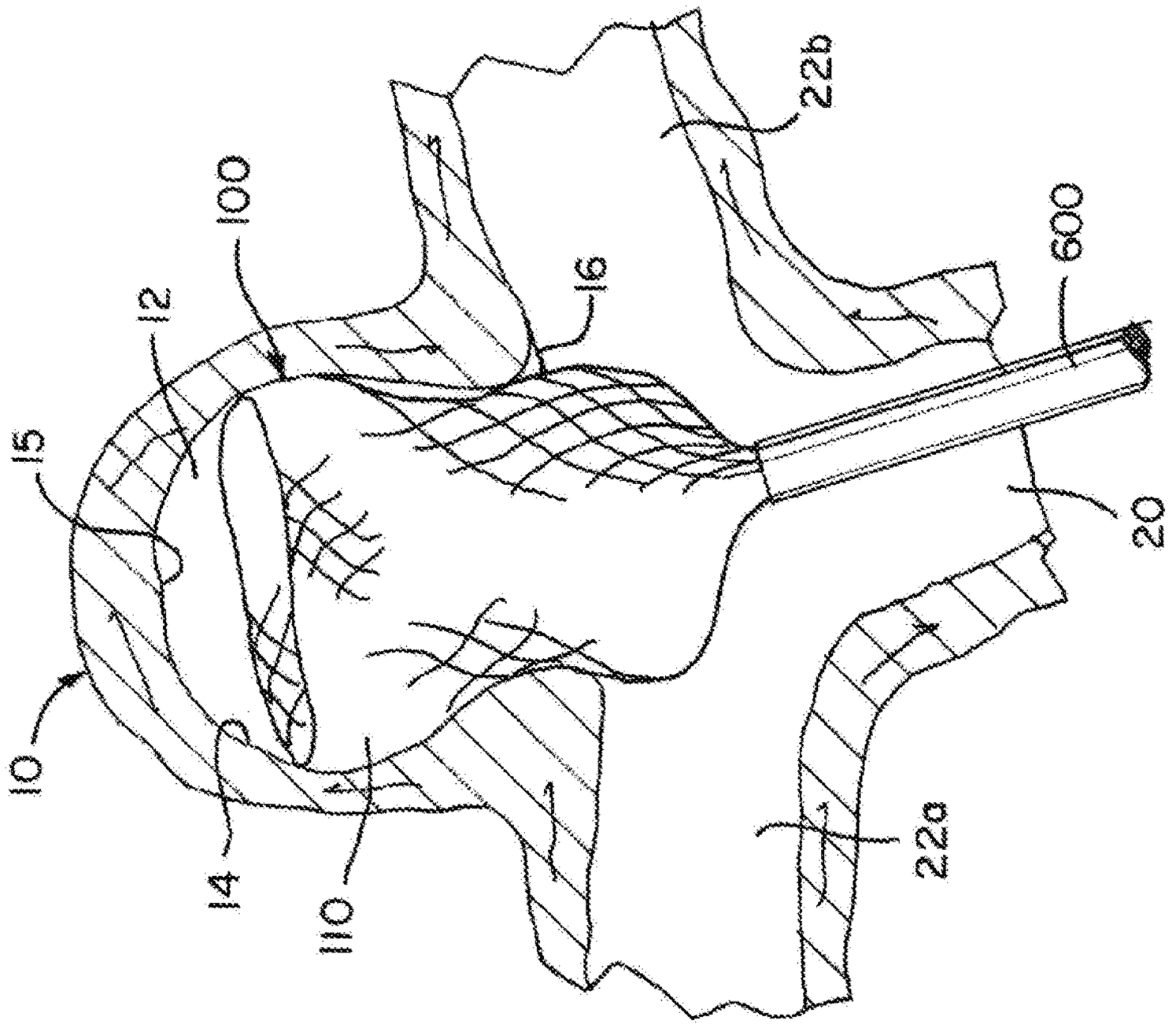

22b
100
16
600
12
15
20
10
14
110
22a

FIG. 3A

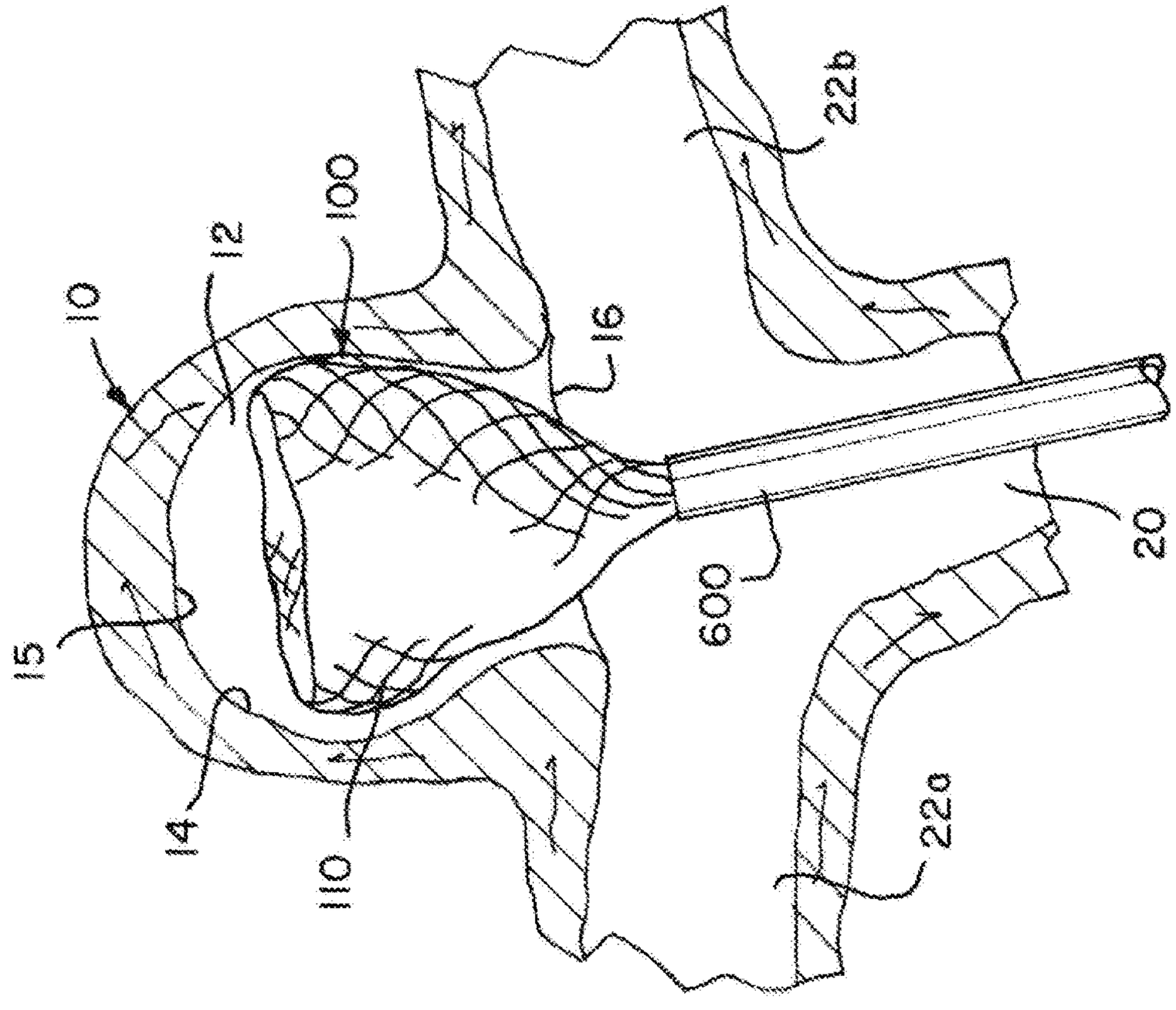

22b
100
12
10
16
15
600
20
14
110
22a

FIG. 3C

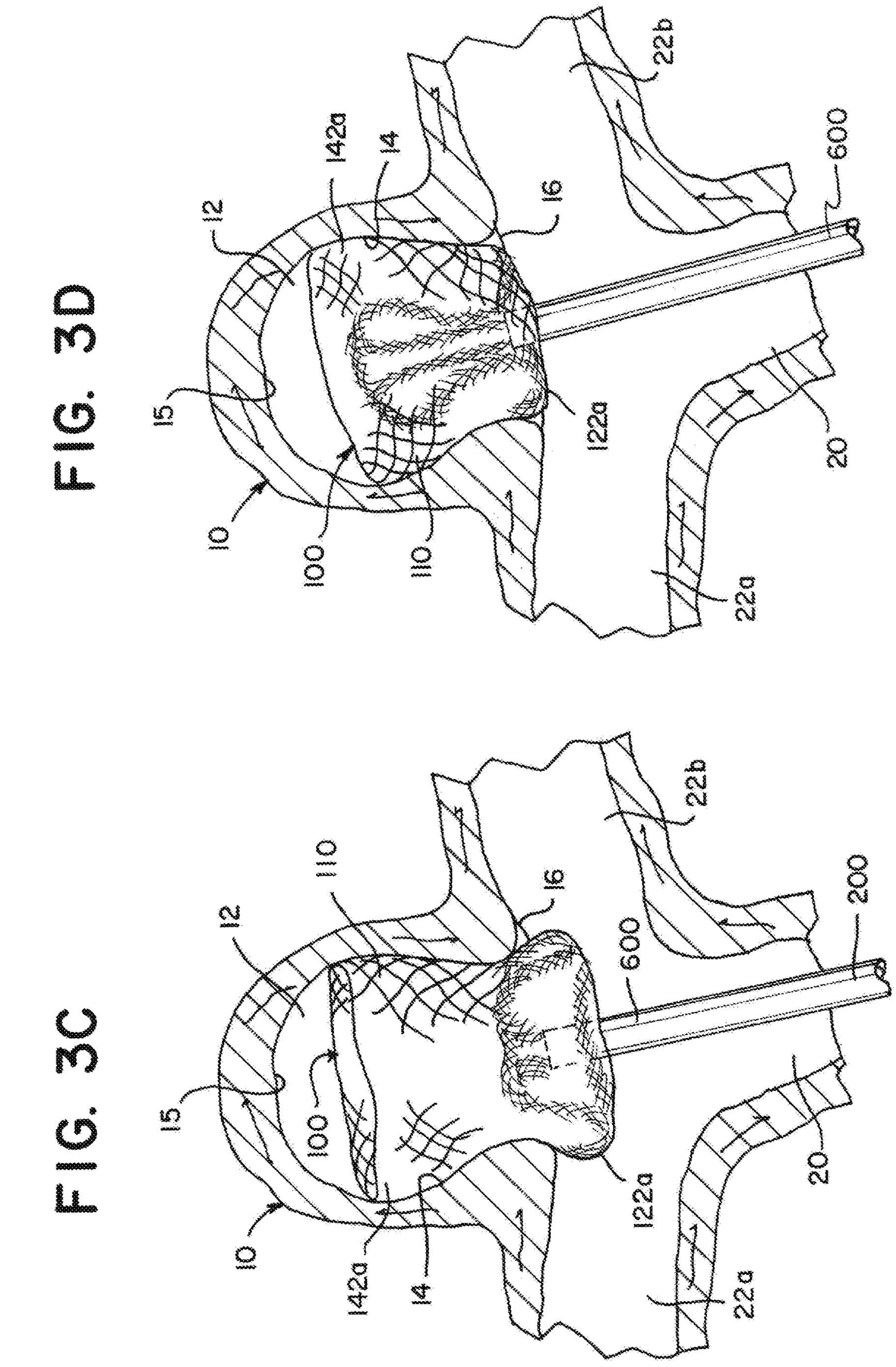


FIG. 3E

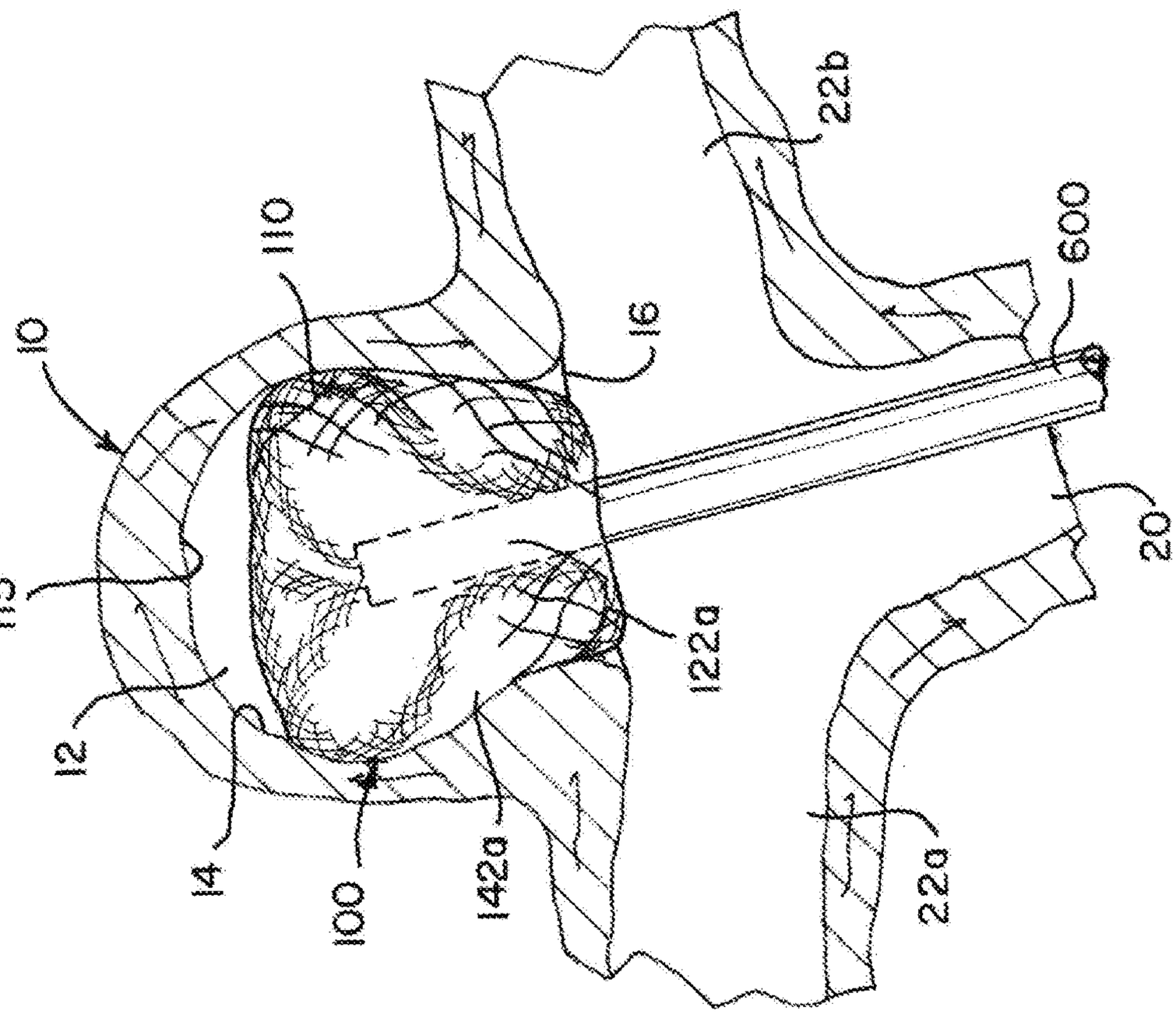

10
14
144a
16
22b
600
124a
112
150
115
20
12
146a
100
110
22a

FIG. 3F

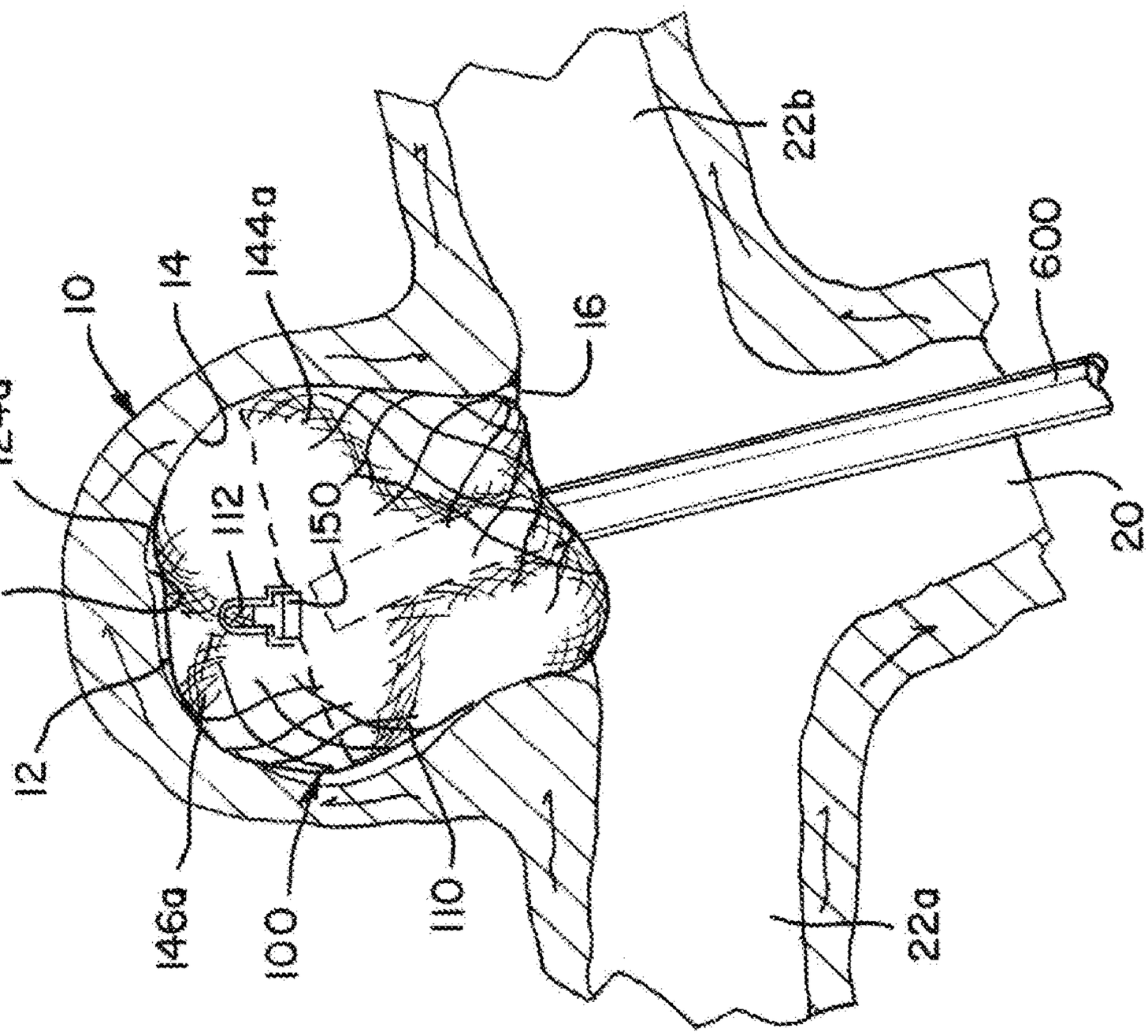

110
22b
600
10
16
115
20
12
14
100
142a
122a
22a

FIG. 3G

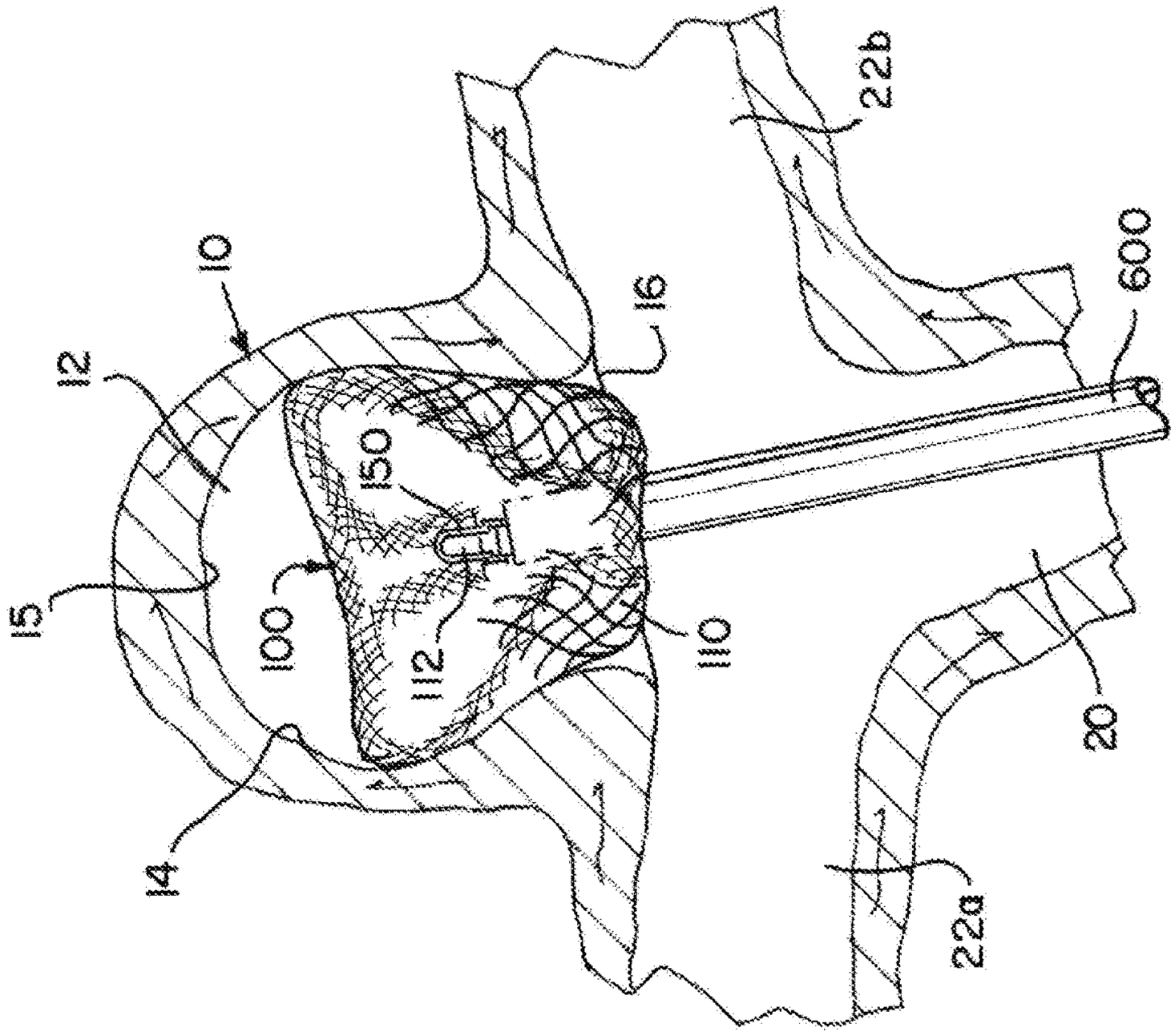
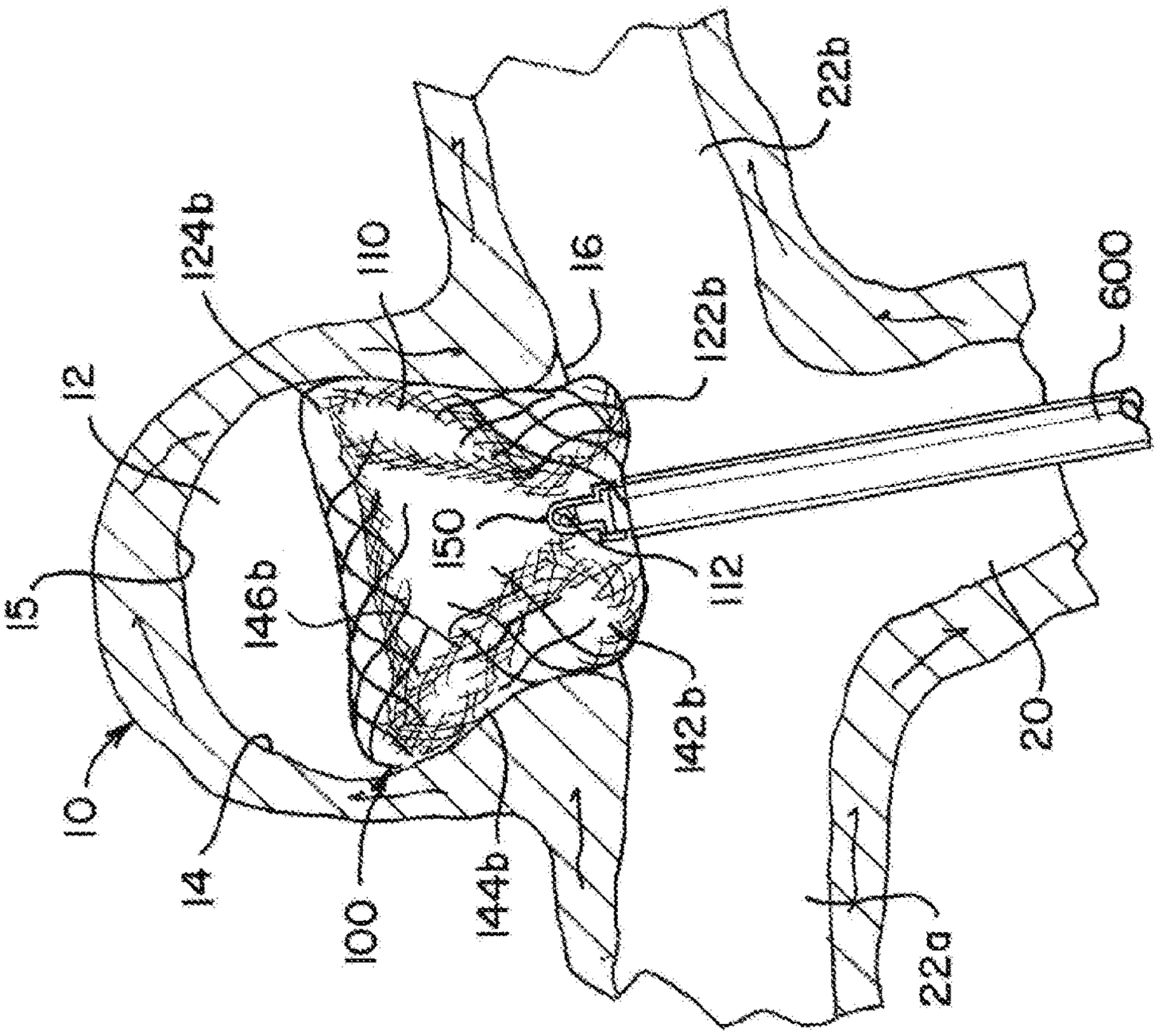

10
12
14
15
16
20
22a
22b
100
110
112
150
600

FIG. 3H


10
12
14
15
16
20
22a
22b
100
110
112
124b
142b
144b
146b
150
600

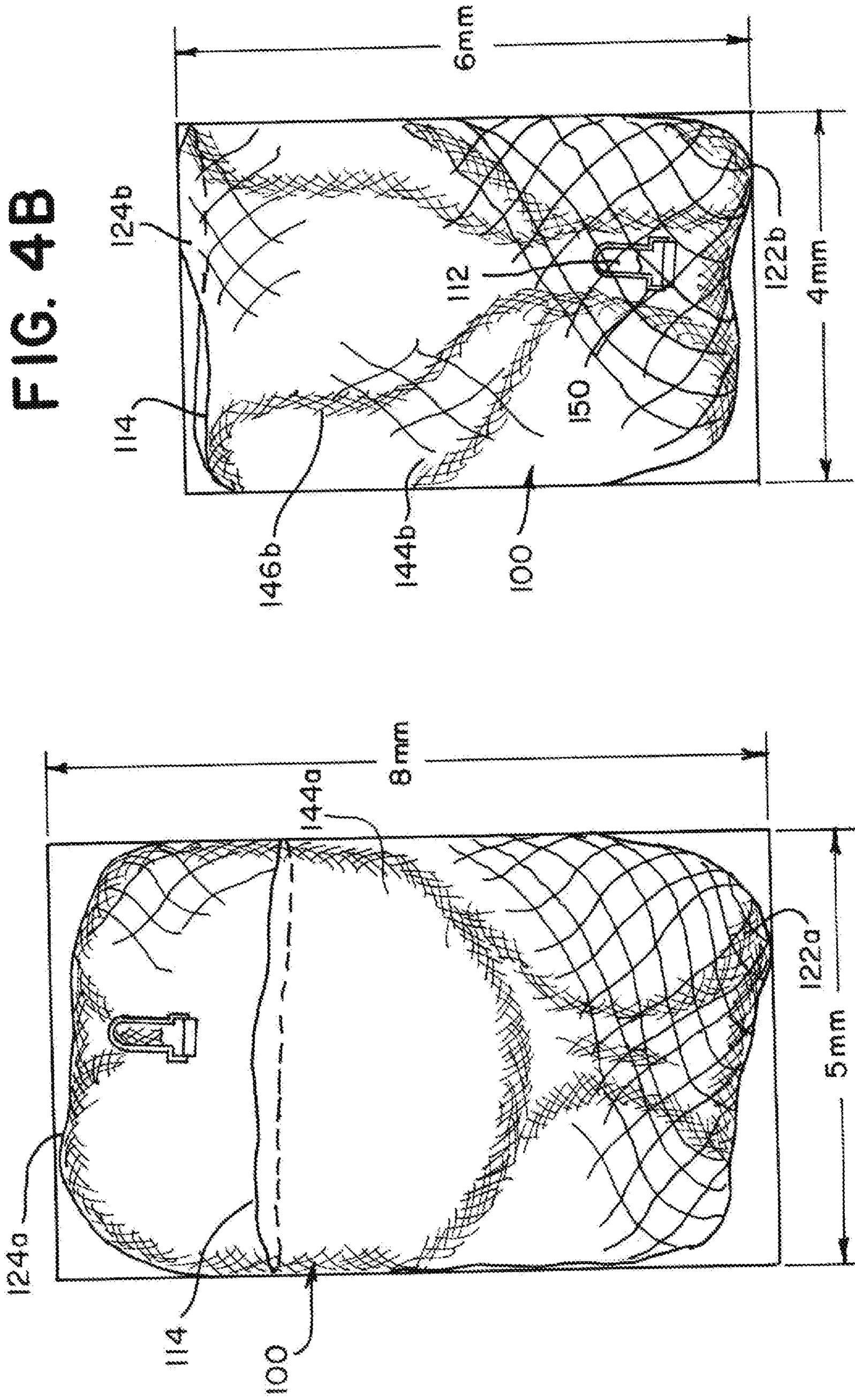

6mm
124b
112
122b
4mm
114
150
146b
144b
100

FIG. 4B

8mm
144a
122a
5mm
124a
114
100

FIG. 4A

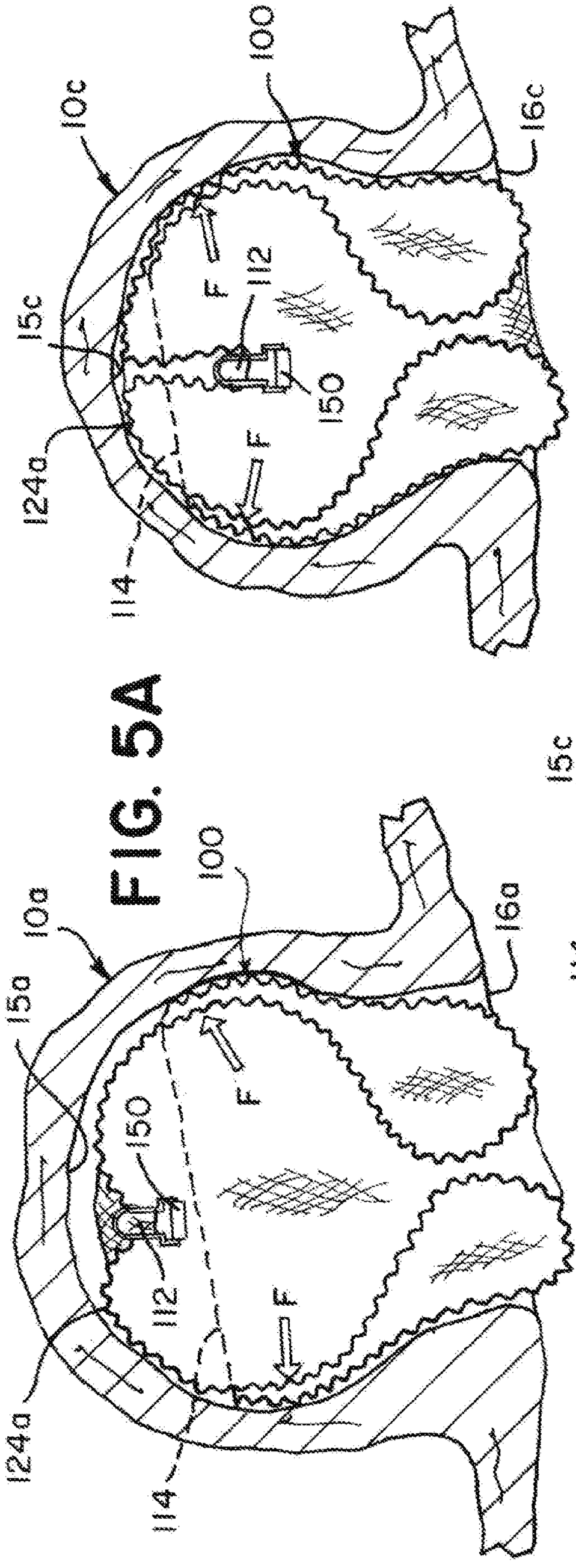


FIG. 5B

FIG. 5A

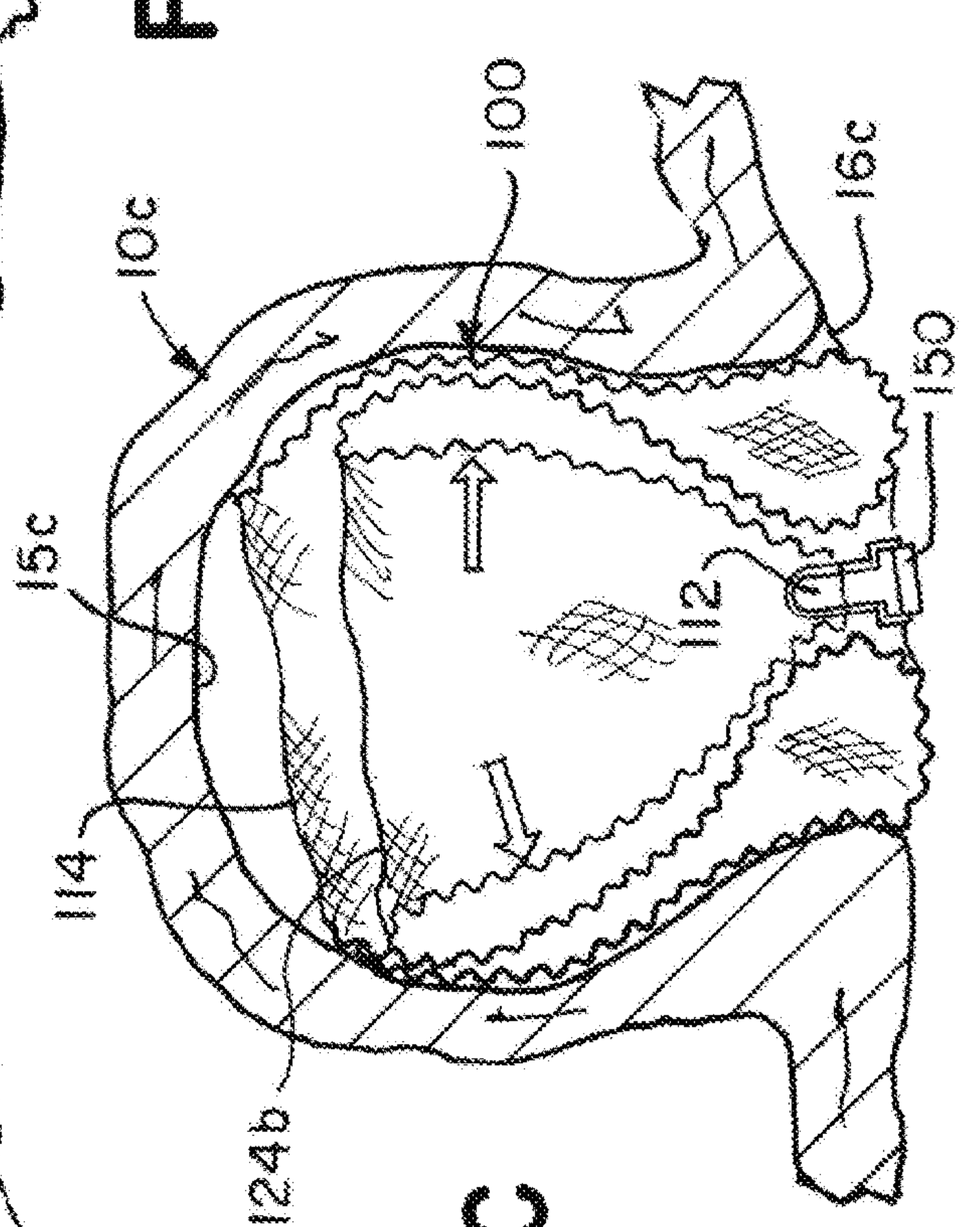


FIG. 5C

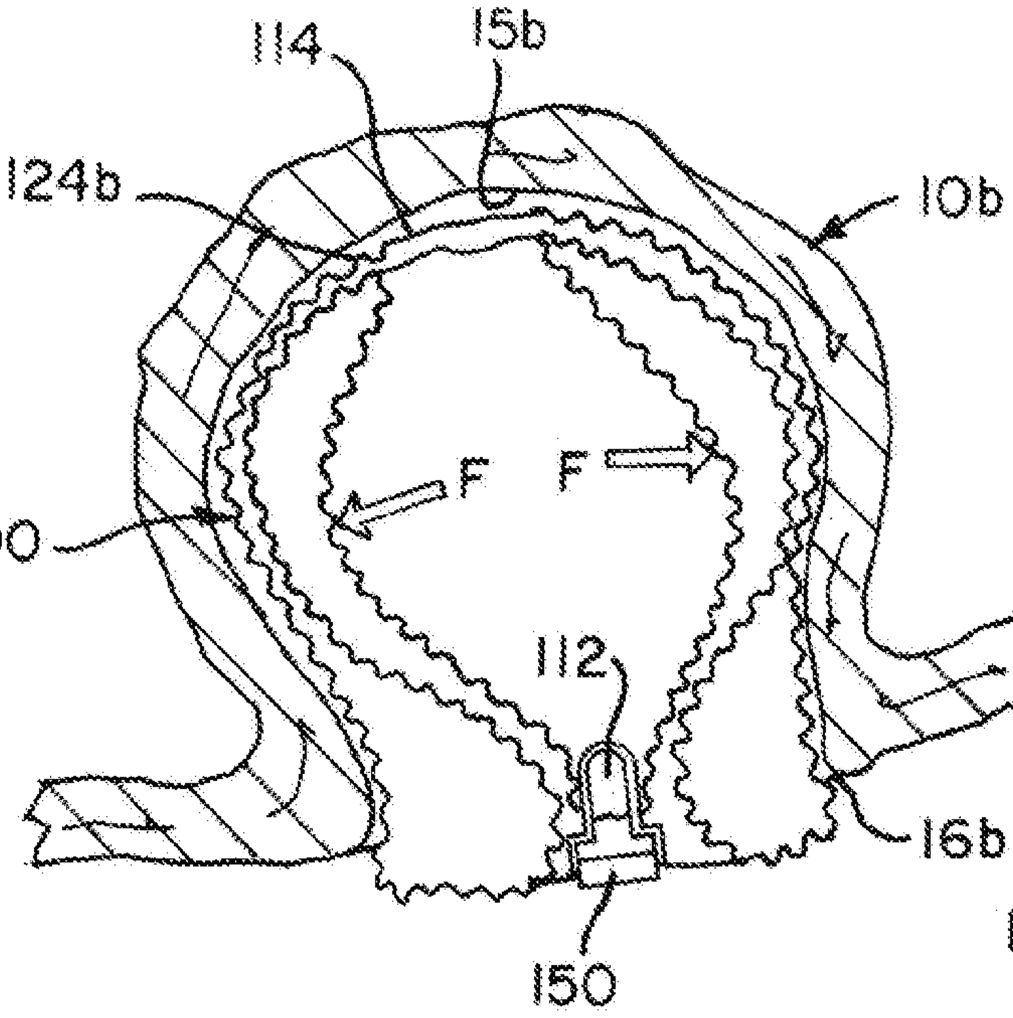


FIG. 5D

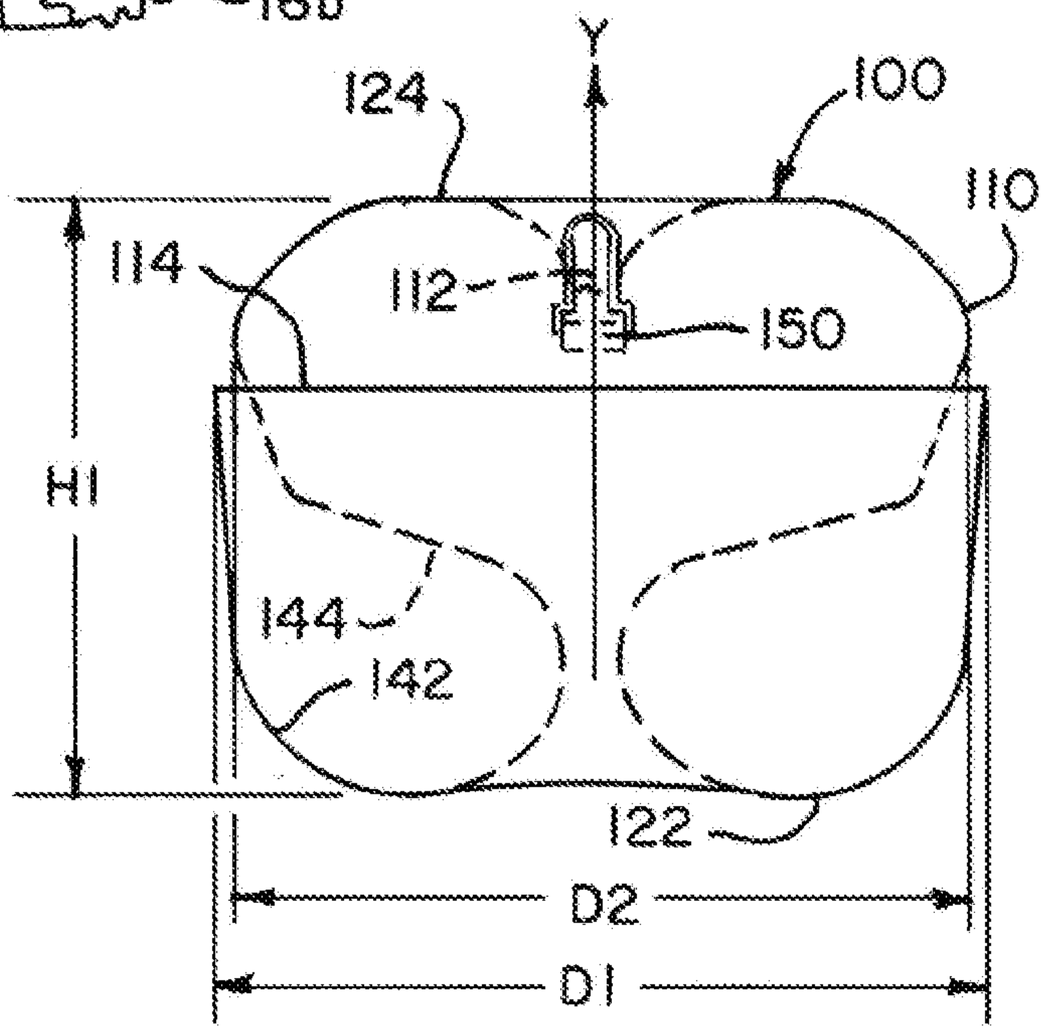


FIG. 6A

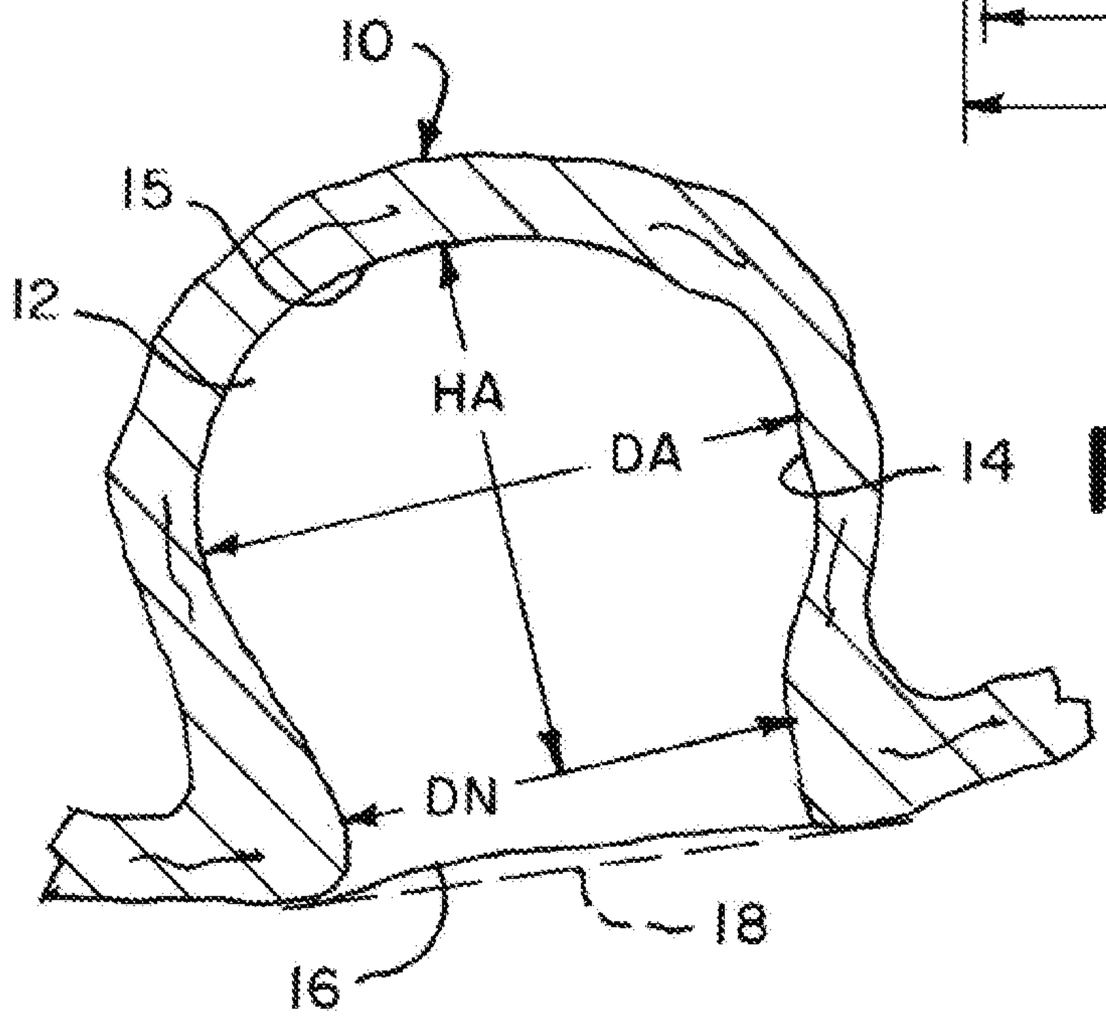


FIG. 6B

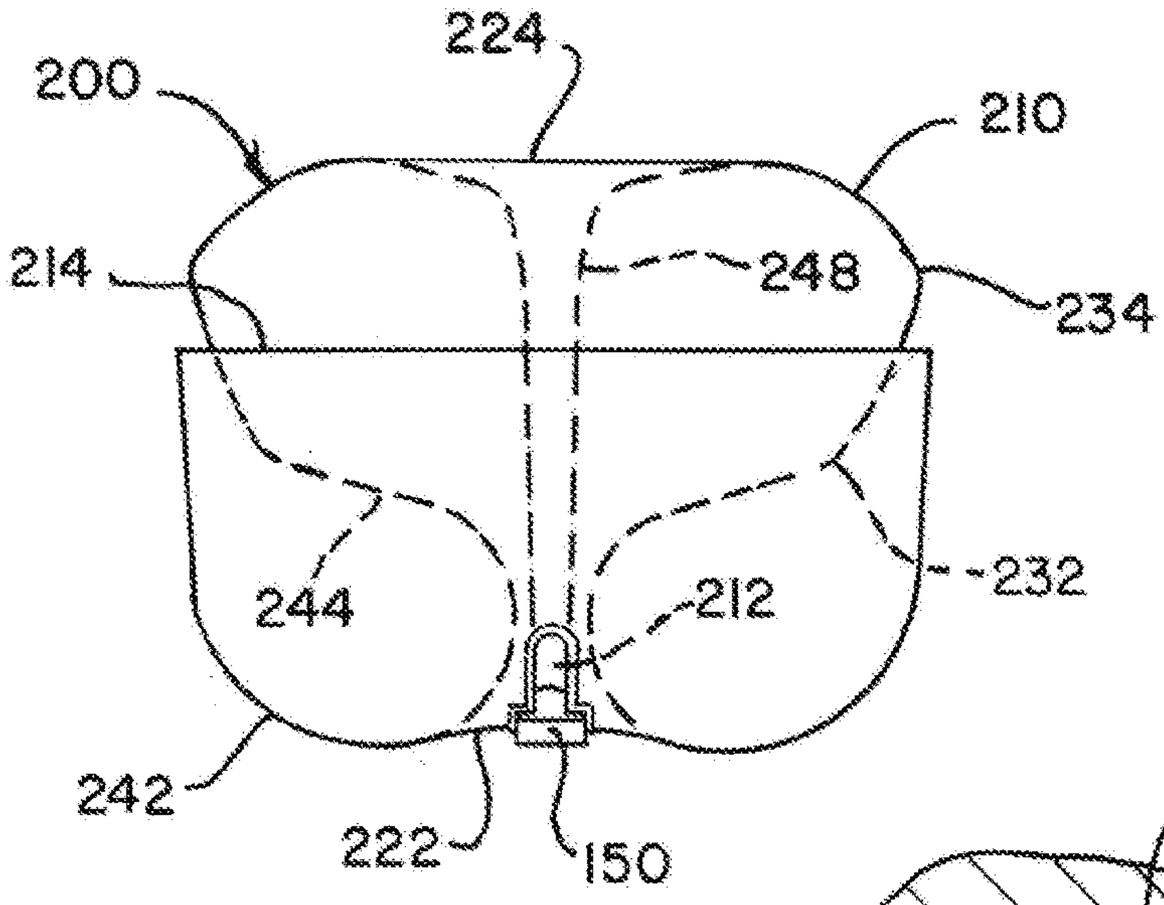


FIG. 7A

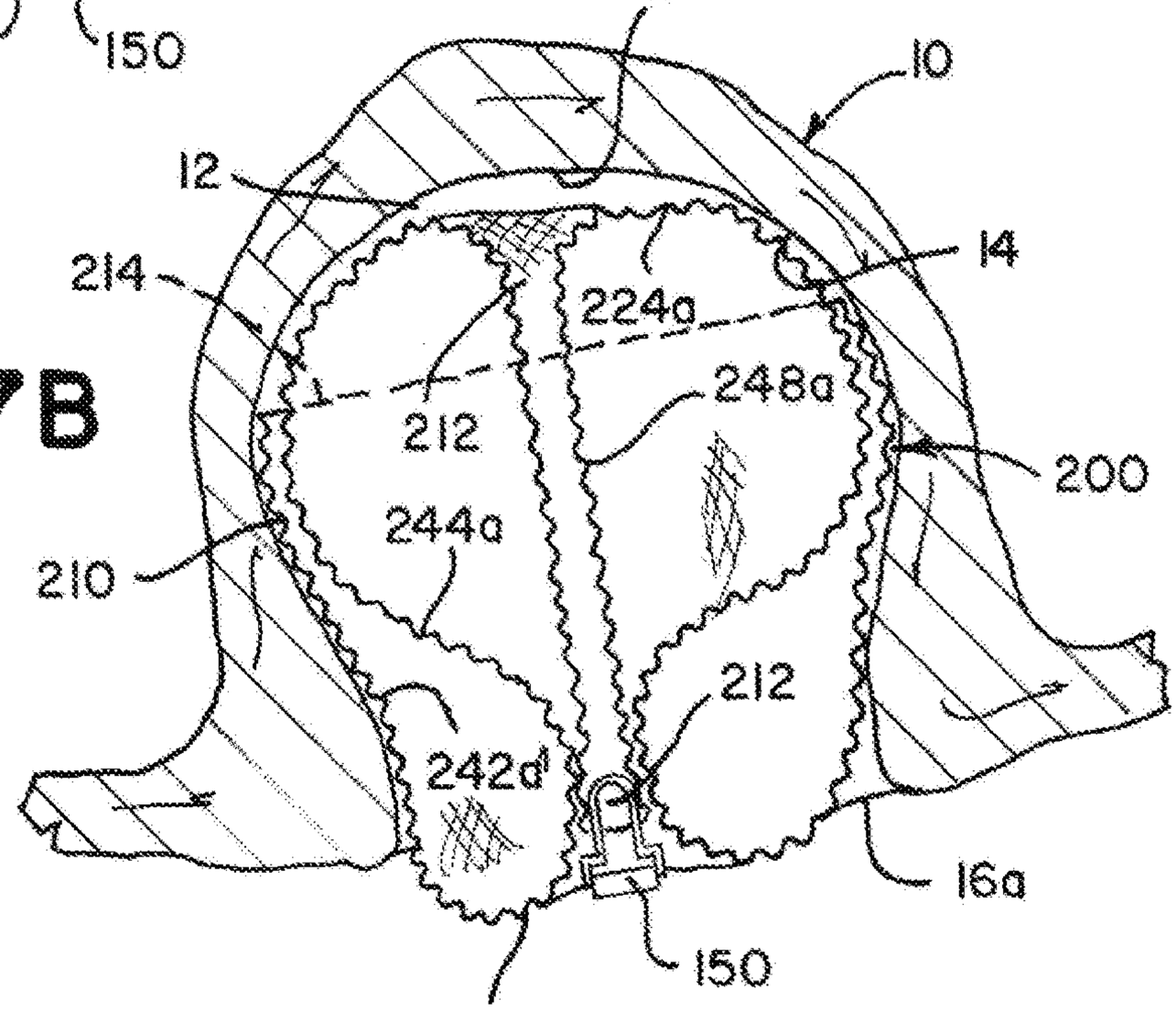


FIG. 7B

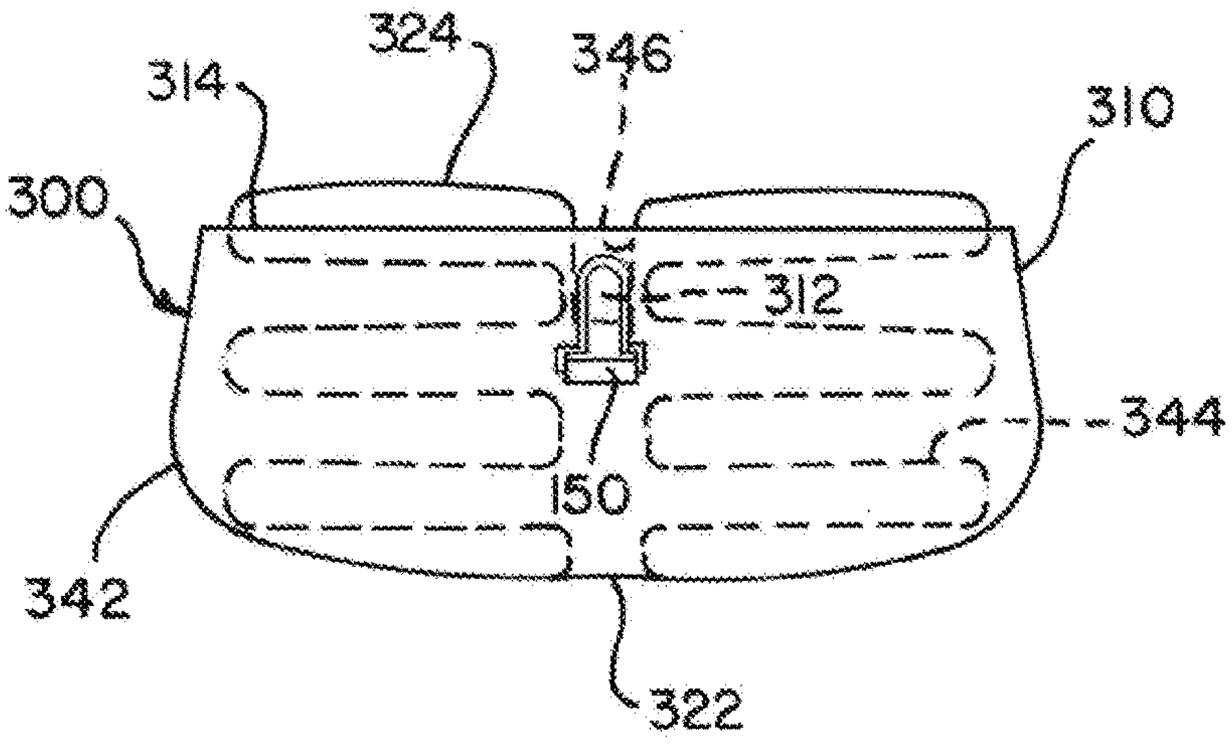


FIG. 8A

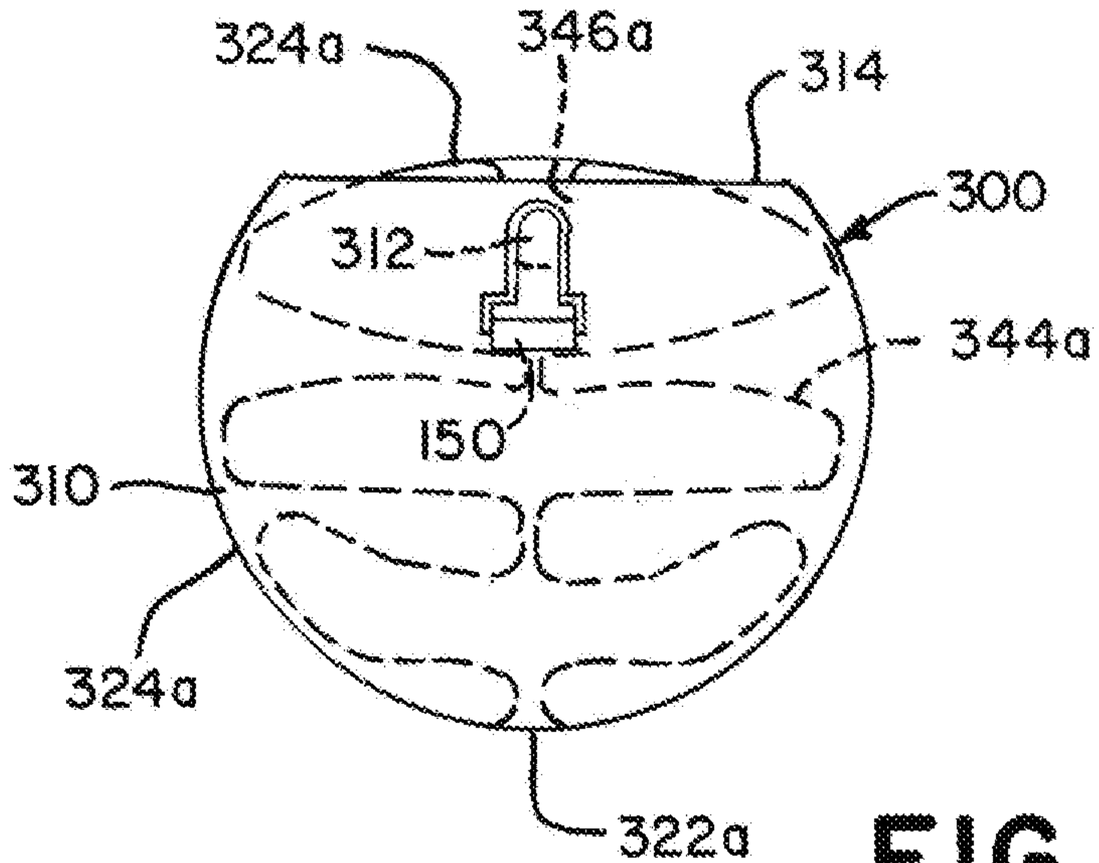


FIG. 8B

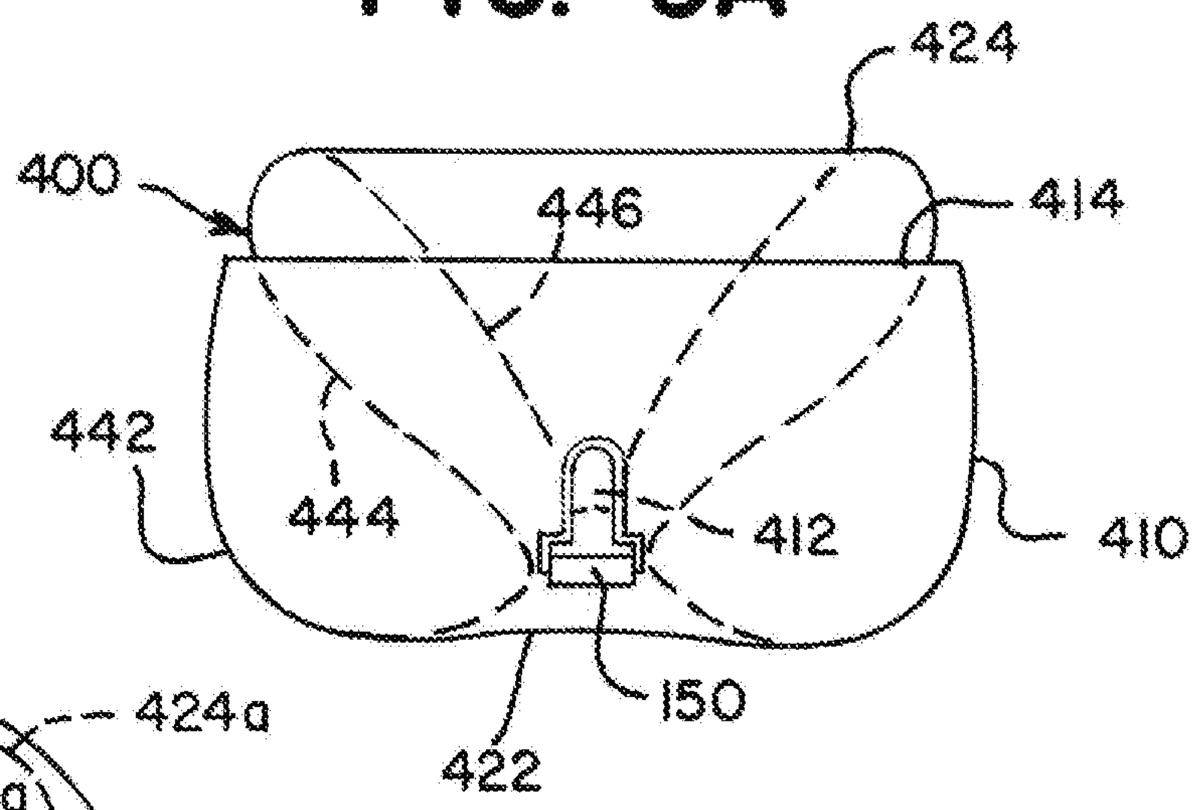


FIG. 9A

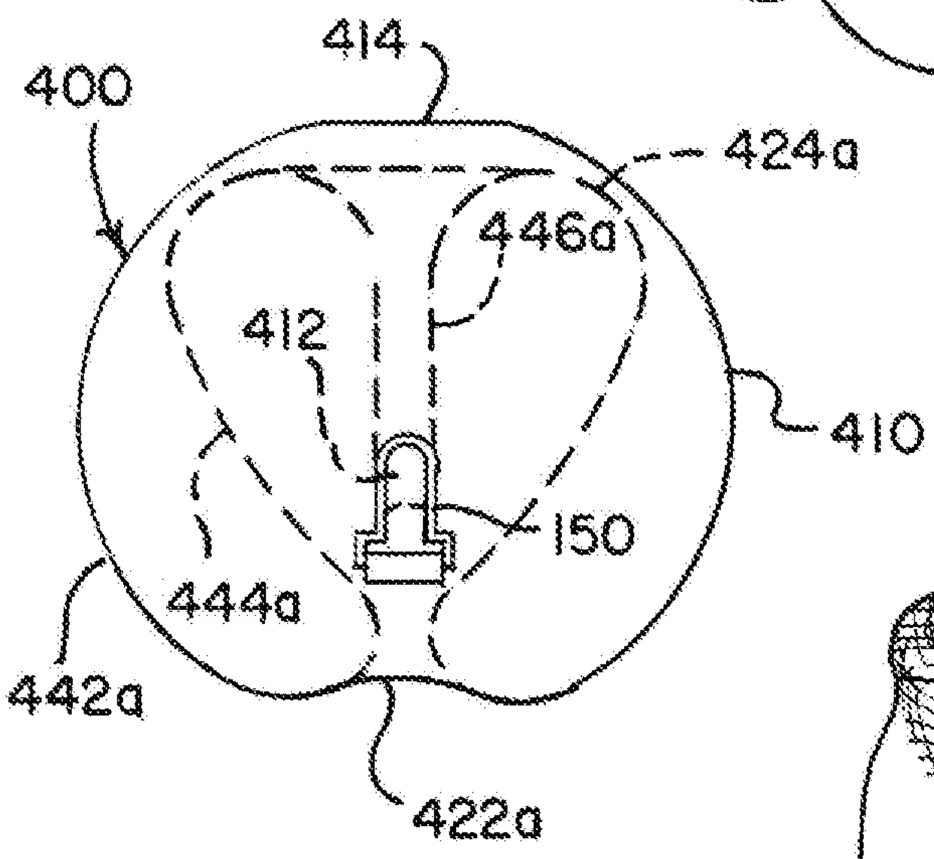


FIG. 9B

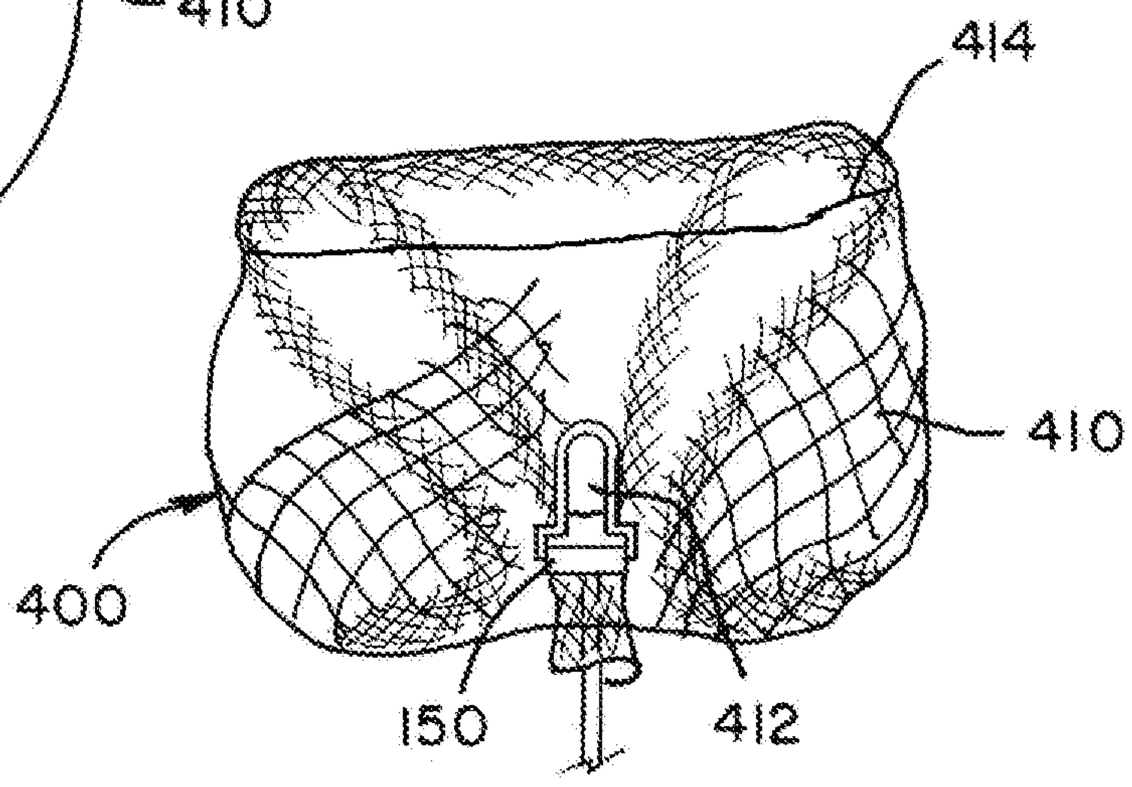


FIG. 10

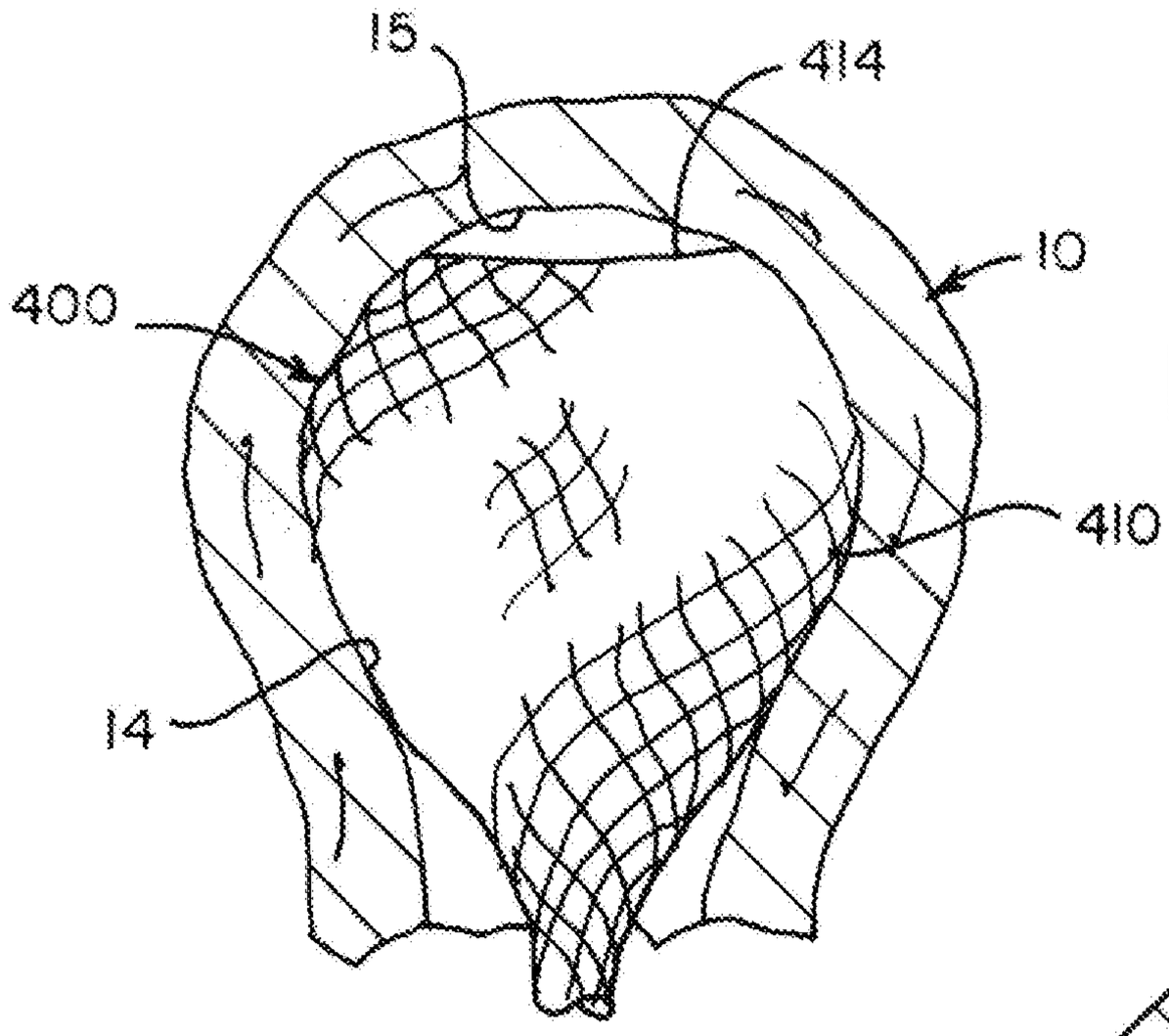


FIG. 11A

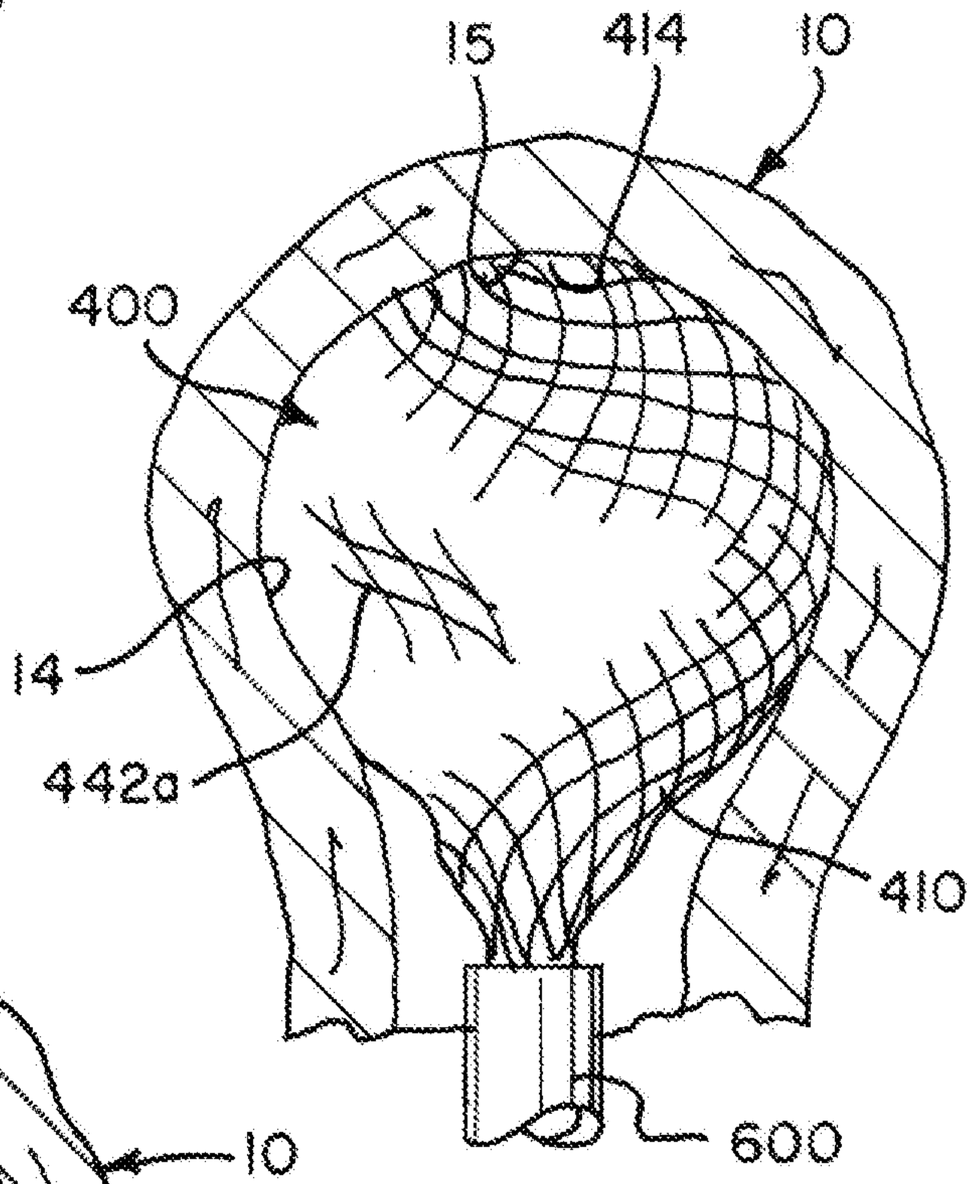


FIG. 11B

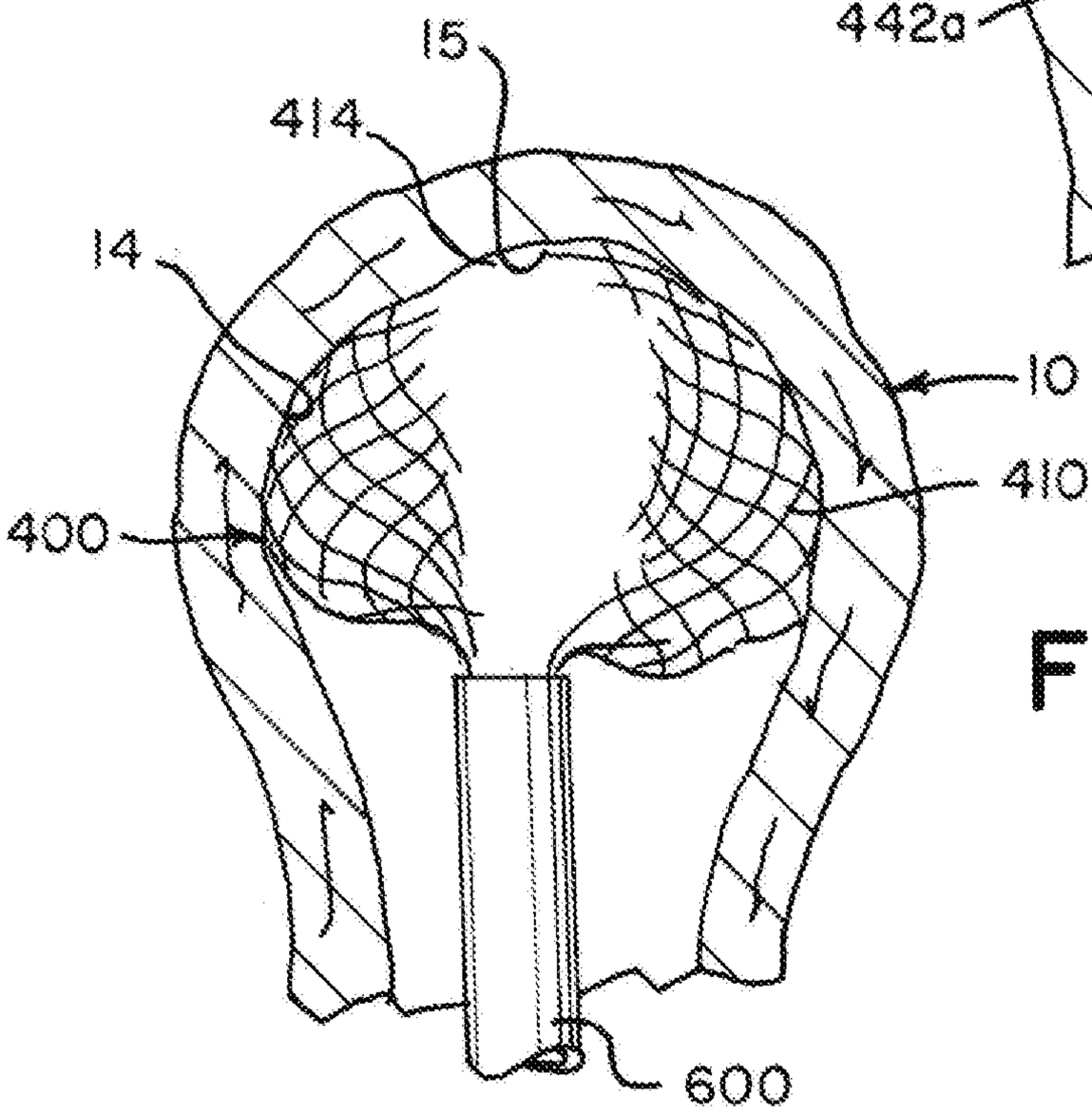


FIG. 11C

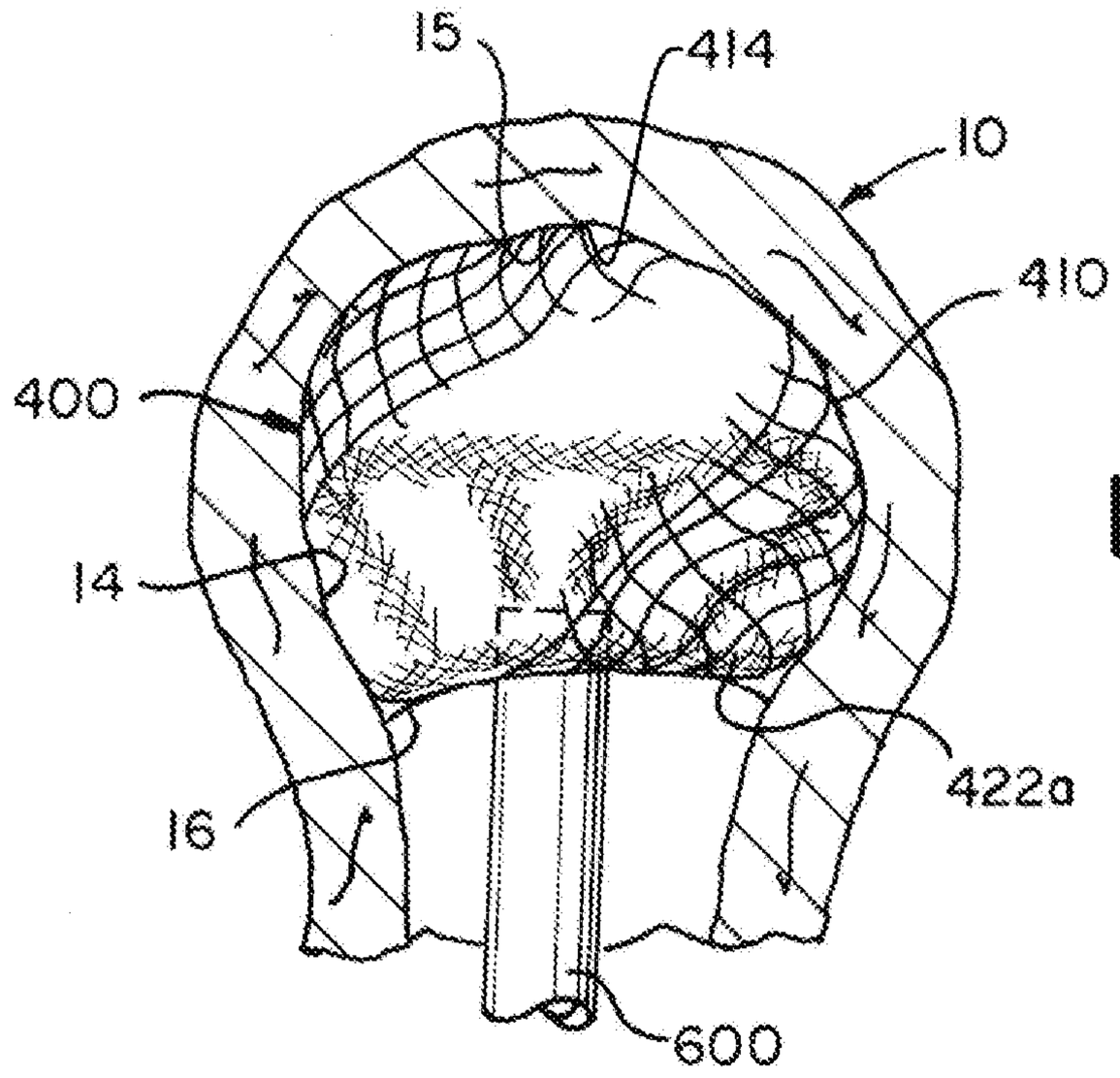


FIG. 11D

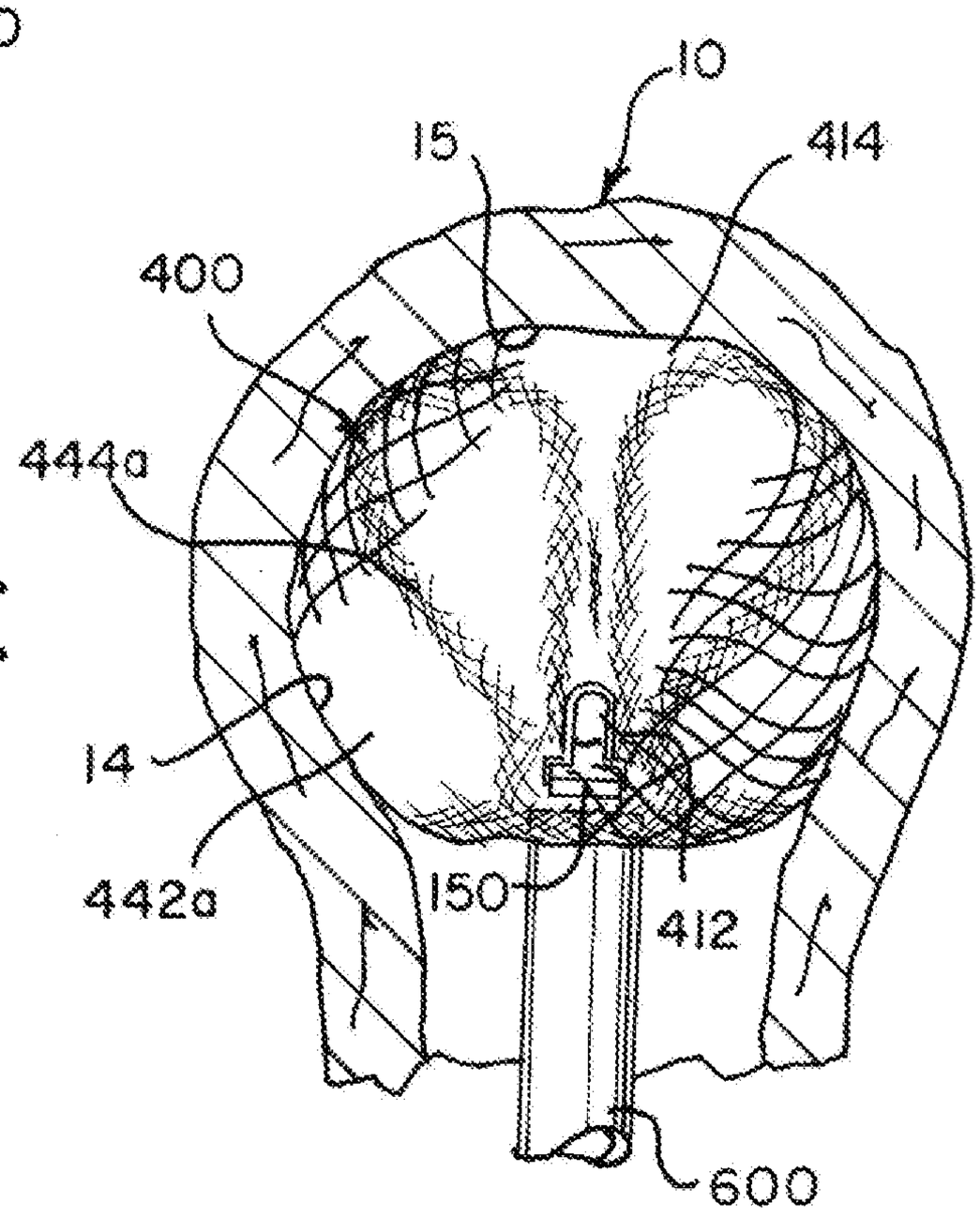


FIG. 11E

LAYERED BRAIDED ANEURYSM TREATMENT DEVICE

FIELD OF INVENTION

The present invention generally relates to medical instruments, and more particularly, to embolic implants for aneurysm therapy.

BACKGROUND

Cranial aneurysms can be complicated and difficult to treat due to their proximity to critical brain tissues. Prior solutions have included endovascular treatment whereby an internal volume of the aneurysm sac is removed or excluded from arterial blood pressure and flow. Current alternatives to endovascular or other surgical approaches can include intravascularly delivered treatment devices that fill the sac of the aneurysm with embolic material or block the entrance or neck of the aneurysm. Both approaches attempt to prevent blood flow into the aneurysm. When filling an aneurysm sac, the embolic material clots the blood, creating a thrombotic mass within the aneurysm. When treating the aneurysm neck, blood flow into the entrance of the aneurysm is inhibited, inducing venous stasis in the aneurysm and facilitating a natural formation of a thrombotic mass within the aneurysm.

Current intravascularly delivered devices typically utilize multiple embolic coils to either fill the sac or treat the entrance of the aneurysm. Naturally formed thrombotic masses formed by treating the entrance with embolic coils can result in improved healing compared to aneurysm masses packed with embolic coils because naturally formed thrombotic masses can reduce the likelihood of distention from arterial walls and facilitate reintegration into the original parent vessel shape along the neck plane. However, embolic coils delivered to the neck of the aneurysm can potentially have the adverse effect of impeding the flow of blood in the adjoining blood vessel, particularly if the entrance is overpacked. Conversely, if the entrance is insufficiently packed, blood flow can persist into the aneurysm. Treating certain aneurysm morphology (e.g. wide neck, bifurcation, etc.) can require ancillary devices such a stents or balloons to support the coil mass and obtain the desired packing density. Once implanted, the coils cannot easily be retracted or repositioned. Furthermore, embolic coils do not always effectively treat aneurysms as aneurysms treated with multiple coils often recanalize or compact because of poor coiling, lack of coverage across the aneurysm neck, blood flow, or large aneurysm size.

Alternatives to embolic coils are being explored, for example a tubular braided implant is disclosed in US Patent Publication Number 2018/0242979, incorporated herein by reference. Tubular braided implants have the potential to easily, accurately, and safely treat an aneurysm or other arterio-venous malformation in a parent vessel without blocking flow into perforator vessels communicating with the parent vessel. Compared to embolic coils, however, tubular braided implants are a newer technology, and there is therefore capacity for improved geometries, configurations, delivery systems, etc. for the tubular braided implants. For instance, delivery of tubular braided implants can require unique delivery systems to prevent the braid from inverting or abrading when pushed through a microcatheter, and some simple delivery systems that push embolic coils through microcatheters from their proximal end may not be effective to deliver tubular braids.

There is therefore a need for improved methods, devices, and systems for implants for aneurysm treatment.

SUMMARY

It is an object of the present invention to provide systems, devices, and methods to meet the above-stated needs. Generally, it is an object of the present invention to provide a braided implant that can secure within an aneurysm sac and occlude a majority of the aneurysm's neck. The implant can include a tubular braid that can be set into a predetermined shape, compressed for delivery through a microcatheter, and implanted in at least one implanted position that is based on the predetermined shape and the geometry of the aneurysm in which the braid is implanted.

In some examples presented herein, when compressed, the implant can be sufficiently short to mitigate friction forces produced when the implant is delivered unsheathed through the microcatheter allowing for a more simplistic delivery system compared to some other known braided embolic implant delivery systems.

In some examples presented herein, when the implant is implanted, a majority of the aneurysm sac can be free from embolic material to facilitate the formation of a thrombotic mass that is primarily naturally formed.

In some examples presented herein, the tubular braid can be implanted in two distinct implanted shapes, depending on the size of the aneurysm, allowing for treatment of a wider range of aneurysm sizes compared to some other known braided embolic implants.

In some examples presented herein, when implanted, the tubular braid can have a compaction resistant column extending across a majority of the height of the aneurysm and positioned centrally within the aneurysm sac.

An example implant can include a tubular braid having an open end and a pinched end. The tubular braid can have a predetermined shape that has two inversions that divide the braid into three segments. In the predetermined shape, the braid can have an outer segment that extends between the open end and a first of the two inversions, a middle segment that extends between the two inversions and is encircled by the open end, and an inner segment that extends between the second of the two inversions and the pinched end of the tubular braid and is surrounded by the middle segment.

When in the predetermined shape, the tubular braid can have a height measured between the two inversions and a substantially radially symmetrical shape having an outermost diameter. The ratio of outermost diameter to height can be between about 2:1 and about 1:3 or, more specifically, between about 2:1 and about 1:1. In the predetermined shape the middle segment can have maximum diameter that is equal to the diameter of the open end. When compressed, the tubular braid can be extended longitudinally to a single layer of braid having a length measured from the open end to the pinched end. The ratio of the outermost diameter in the predetermined shape to length in the compressed, delivery shape can be between about 0.2 and about 0.3.

The length of the tubular braid in the delivery shape can be between about 10 mm an about 40 mm, depending on the size of the aneurysm being treated.

A collection of implants, each having a uniquely shaped tubular braid can be created to provide a catalogue of implants for treating aneurysms ranging in diameter and height. Each implant in the collection can be suitable for treating aneurysms with a sub-range of diameters and a sub range of heights.

The tubular braid can have two distinct implanted shapes based on the predetermined shape and constrained by the geometry of an aneurysm in which the tubular braid is implanted. In other words, the implant can be implanted in either a larger aneurysm or a smaller aneurysm, the smaller aneurysm having a height measuring less than the height of the larger aneurysm, and the tubular braid can take one of the two implanted shapes when implanted in the larger aneurysm and the tubular braid can take on the other of the implanted shapes when implanted in the smaller aneurysm. In either implanted shape, the first, outer segment of the predetermined shape can be positioned to form an outer layer that juxtaposes/apposes an aneurysm wall and the inversion adjacent to the outer segment in the predetermined shape can be positioned to form a proximal inversion at an aneurysm neck. When implanted in the larger aneurysm, the second, middle segment of the predetermined shape can form a sack that apposes a portion of the aneurysm wall and apposes the outer layer of the braid, the pinched end can be suspended within the sack of the braid, and the open end can encircle the sack. When implanted in the smaller aneurysm, the middle segment of the predetermined shape can be folded to form a middle layer that apposes the outer layer and an inner layer that apposes the middle layer, the open end can be positioned near the fold dividing the middle and inner layers, and the pinched end can be positioned near the proximal inversion and aneurysm neck. The tubular braid in the predetermined shape can have a bend in the middle, second segment, and when tubular braid is in the smaller aneurysm implanted shape, the middle segment can fold at the bend to separate the middle layer from the inner layer.

An example implant having the tubular braid having two distinct implanted shapes can treat aneurysms within a range of sizes including an aneurysm having a diameter of 4 mm and a height of 6 mm, an aneurysm having a diameter of 5 mm and a height of 8 mm, and an aneurysm having a diameter of 6 mm and a height of 6 mm. Additionally, or alternatively, the implant can be suitable for treating aneurysms within a continuum of aneurysm sizes, the continuum bounded by and including aneurysm diameters between 4 mm and 5 mm and heights between 6 mm and 8 mm. The implant capable of treating aneurysms having the aforementioned sizes, when compressed for delivery through a microcatheter can have a length measuring between about 22 mm and about 25 mm.

As an alternative to having two distinct implanted shapes, the implant can have an implanted shape that includes a compaction resistant post extending within an inner sack of the braid and extending between a proximal inversion near an aneurysm neck and a distal inversion near a distal portion of an aneurysm wall. In the implanted shape, the tubular braid can have an outer layer that corresponds to the outer segment in the predetermined shape, the inner sack in the implanted shape can correspond to the middle segment in the predetermined shape, the compaction resistant post can correspond to the inner, third segment in the predetermined shape, and the distal and proximal inversions can correspond to the two inversions in the predetermined shape. The compaction resistant post can serve to inhibit the implant from impacting when implanted in the aneurysm.

An example method of treating an aneurysm can include one or more of the following steps presented in no particular order, and the method can include additional steps not included here. A tubular braid having an open end and a pinched end can be selected and shaped to a predetermined shape. The predetermined shape can be formed by inverting the braid to form a distal inversion, moving the open end over some or all of the braid to form a proximal inversion, shaping a first segment that extends between the open end and the proximal inversion, shaping a second segment that extends between the two inversions, positioning the open end to encircle the second segment, shaping a third segment that extends between the distal inversion and the pinched end of the braid, and positioning the second segment to surround the third segment. Forming the predetermined shape can further include shaping the open end and second segment so that the open end has a diameter greater than or equal to the maximum diameter of the second segment.

The tubular braid can be formed in the predetermined shape such that the tubular braid is implantable in two distinct implanted shapes and in either of two aneurysms having differing heights such that the braid takes on one implanted shape in the taller aneurysm and the second, different implanted shape in the shorter aneurysm. The example method can further include reshaping the tubular braid into one of the two distinct implanted shapes. When the tubular braid is reshaped for the taller aneurysm, the first segment can be reshaped to form an outer braid layer that apposes an aneurysm wall of the taller aneurysm, the proximal inversion can be positioned at the neck of the taller aneurysm, and the second segment can be reshaped to form a sack that nests within the outer layer and also apposes the aneurysm wall of the taller aneurysm. When the tubular braid is reshaped for the shorter aneurysm, the first segment can be reshaped to form an outer braid layer that apposes an aneurysm wall of the shorter aneurysm, the proximal inversion can be positioned at the neck of the shorter aneurysm, and the second segment can be folded to form a middle braid layer that apposes the outer layer and an inner braid layer that apposes the middle layer.

Forming the predetermined shape can further include forming a bend in the second segment, and when the tubular braid is reshaped for the shorter aneurysm, the second segment can be folded at the bend to form the fold that separates the middle braid layer and the inner braid layer.

When the tubular braid is reshaped for the taller aneurysm, the pinched end can be suspended within the sack. When the tubular braid is reshaped for the smaller aneurysm, the pinched end can be positioned near the proximal inversion.

When the tubular braid is reshaped for the taller aneurysm, the open end can encircle the sack. When the tubular braid is reshaped for the shorter aneurysm, the open end can be positioned near the fold separating the middle braid layer and the inner braid layer.

The method can further include shaping the tubular braid into a delivery shape to be delivered through a microcatheter. The tubular braid can have a length in the delivery shape that is measured between the open end and the pinched end. When the tubular braid is shaped to the predetermined shape, it can be shaped to have an outermost diameter. The length of the tubular braid in the delivery shape can measure between 3.5 and 5 times that of the outermost diameter of the tubular braid in the predetermined shape.

In the predetermined shape, the outermost diameter can be shaped to be between 2 and 1/3 times the height of the tubular braid.

When the tubular braid is shaped to the predetermined shape, the tubular braid can be shaped to be suitable to be implanted in an aneurysm having a diameter of 4 mm and a height of 6 mm, an aneurysm having a diameter of 5 mm and a height of 8 mm, and an aneurysm having a diameter of 6 mm and a height of 6 mm. Additionally, or alternatively,

when the tubular braid is shaped to the predetermined shape, the tubular braid can be shaped to be suitable for treating a continuum of aneurysm sizes including aneurysms having diameters between 4 mm and 5 mm and heights between 6 mm and 8 mm. The tubular braid that is suitable for treating aneurysms sized as above can be extended to a single layer delivery shape having a length measuring between about 22 mm and about 25 mm, the delivery shape sized to be delivered through a microcatheter.

The method can further include positioning the proximal inversion on a proximal side of a plane defining a boundary between an aneurysm and blood vessel branches. The first segment can be reshaped to appose an aneurysm wall and the second segment can be reshaped to provide an outwardly radial force in the plane. The force can be sufficient to appose the first segment to the aneurysm neck. The force can also be sufficient to resist compaction of the implant within the aneurysm.

The method can further include collapsing the implant to fit within a microcatheter and pushing the pinched end of the unsheathed tubular braid through a majority of the length of the microcatheter to an aneurysm within a patient.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further aspects of this invention are further discussed with reference to the following description in conjunction with the accompanying drawings, in which like numerals indicate like structural elements and features in various figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating principles of the invention. The figures depict one or more implementations of the inventive devices, by way of example only, not by way of limitation.

FIG. **1**A is an illustration of an example implant having a tubular braid in a predetermined shape according to aspects of the present invention;

FIG. **1**B is an illustration of the example implant with the tubular braid in a first implanted shape according to aspects of the present invention;

FIG. **1**C is an illustration of the example implant with the tubular braid in a second implanted shape according to aspects of the present invention;

FIGS. **2**A through **2**H are illustrations of an implant having a tubular braid that expands to a predetermined shape similar to as illustrated in FIG. **1**A as the tubular braid exits a microcatheter according to aspects of the present invention;

FIGS. **3**A through **3**H are illustrations of the implant showing the tubular braid expanding to a first implanted shape and a second implanted shape within an aneurysm according to aspects of the present invention;

FIG. **4**A is an illustration of the implant showing the tubular braid expanded in the first implanted shape in a tube having a 5 mm diameter according to aspects of the present invention;

FIG. **4**B is an illustration of the implant showing the tubular braid expanded in the second implanted shape in a tube having a 4 mm diameter according to aspects of the present invention;

FIGS. **5**A through **5**D are illustrations of the example implant as illustrated in FIGS. **1**A through **1**C implanted in either the first implanted shape or the second implanted shape in aneurysms ranging in size according to aspects of the present invention;

FIGS. **6**A and **6**B are illustrations of measurements of an example implant and an aneurysm according to aspects of the present invention;

FIG. **7**A is an illustration of an example implant having a tubular braid in an alternative predetermined shape according to aspects of the present invention;

FIG. **7**B is an illustration of the example implant illustrated in FIG. **7**A with the tubular braid in an implanted shape according to aspects of the present invention;

FIG. **8**A is an illustration of an example implant having a tubular braid in another alternative predetermined shape according to aspects of the present invention;

FIG. **8**B is an illustration of the example implant illustrated in FIG. **8**A with the tubular braid in an implanted shape according to aspects of the present invention;

FIG. **9**A is an illustration of an example implant having a tubular braid in another alternative predetermined shape according to aspects of the present invention;

FIG. **9**B is an illustration of the example implant illustrated in FIG. **9**A with the tubular braid in an implanted shape according to aspects of the present invention;

FIG. **10** is an illustration of an implant having a tubular braid in a predetermined shape similar to as illustrated in FIG. **9**A according to aspects of the present invention; and

FIGS. **11**A through **11**E are illustrations of the implant illustrated in FIG. **10** showing the tubular braid expanding to the implanted shape similar to as illustrated in FIG. **9**B according to aspects of the present invention.

DETAILED DESCRIPTION

Examples presented herein generally include a braided implant that can secure within an aneurysm sac and occlude a majority of the aneurysm's neck. The implant can include a tubular braid that can be set into a predetermined shape, compressed for delivery through a microcatheter, and implanted in at least one implanted position that is based on the predetermined shape and the geometry of the aneurysm in which the braid is implanted. When compressed, the implant can be sufficiently short to mitigate friction forces produced when the implant is delivered unsheathed through the microcatheter allowing for a more simplistic delivery system compared to some other known braided embolic implant delivery systems

FIGS. **1**A through **1**C are illustrations of an example braided implant **100** that can have a predetermined shape as illustrated in FIG. **1**A and two distinct implanted shapes as illustrated in FIGS. **1**B and **1**C. The implant **100** can treat a range of aneurysm sizes including a larger aneurysm **10***a* as illustrated in FIG. **1**B and a smaller aneurysm **10***b* as illustrated in FIG. **1**C. The implant **100** can have a first implanted shape (FIG. **1**B) that can be conducive for treating larger aneurysms **10***a* and a second implanted shape (FIG. **1**C) that can be conducive for treating smaller aneurysms **10***b*. The implant **100** can include a tubular braid **110** having an open end **114** and a pinched end **112**. The implant **100** can include a detachment feature **150** attached to the braid **110** at the pinched end **112**. The tubular braid **110** can be formed in the predetermined shape (FIG. **1**A), collapsed for delivery through a microcatheter, attached to a delivery system at the detachment feature **150**, and implanted in a shape similar to one or the other of the two implanted shapes (FIG. **1**B or FIG. **1**C).

Referring to FIG. **1**A, when in the predetermined shape, the tubular braid **110** can include two inversions **122**, **124**, dividing the braid **110** into three segments **142**, **144**, **146**. In the predetermined shape, the braid **110** can have an outer

segment **142** extending from the open end **114** of the braid **110** to one of the inversions **122**, an inner segment **146** extending from the pinched end **112** of the braid **110** to the other of the inversions **124**, and a middle segment **144** extending between the two inversions **122**, **124**. When in the predetermined shape, the tubular braid **110** can be substantially radially symmetrical about a central vertical axis y (see FIG. **6**A). FIG. **1**A illustrates a profile of each segment **142**, **144**, **146**, and the detachment feature **150** is illustrated as a flat key that can be used with a mechanical implant delivery system (not illustrated).

The tubular braid **110** can be formed into the predetermined shape by first inverting the braid outwardly to separate the inner segment **146** from the middle segment **144** with an inversion **124**, then the middle segment **144** can be shaped over a form to produce the substantially "S" shaped profile illustrated, and finally, the braid **110** can be inverted outwardly again to separate the middle segment **144** from the outer segment **142** with another inversion **122**. If necessary, the braid can be trimmed at the open end **114**. The open end **114** can be positioned to encircle the middle segment **144**. The open end **114** can positioned within the middle third section of the braid's height as illustrated.

It can be advantageous to minimize a neck opening **126** defined by the lower extension of the "S" shape of the middle segment **144** to maximize occlusion of an aneurysm neck when the implant **100** is implanted. The middle segment **144** can have one or more bends **132**, **134**. The bends **132**, **134** can be positioned facilitate the movement of the braid **110** into the second implanted shape illustrated in FIG. **1**C and the bends **132**, **134** can be positioned to stabilize the braid **110** in the first and/or second implanted shape.

The tubular braid **110** can include memory shape material that can be heat set to a predetermined shape, can be deformed for delivery through a catheter, and can self-expand to an implanted shape that is based on the predetermined shape and confined by the anatomy of the aneurysm in which it is implanted.

As illustrated in FIG. **1**B, when in the first implanted shape, the braid **110** can have an outer layer **142***a* contacting the aneurysm's wall **14***a*, a sack **144***a* nested within the outer layer **142***a*, a proximal inversion **122***a* positioned at the aneurysm's neck **16***a*, and a distal inversion **124***a* positioned near a distal portion **15***a* of the aneurysm wall **14***a*. In the first implanted shape, the detachment feature **150** and pinched end **112** of the braid **110** can be suspended within the sack **144***a*.

As illustrated in FIGS. **1**A and **1**B, the tubular braid **110** in the first implanted shape can be radially compressed and vertically extended compared to the predetermined shape. The outer layer **142***a* in the first implanted shape can correspond to the outer layer **142** in the predetermined shape, the proximal inversion **122***a* in the first implanted shape can correspond to the inversion **122** adjacent to the outer layer **142** in the predetermined shape, the sack **144***a* in the first implanted shape can correspond to the middle segment **144** in the predetermined shape, the distal inversion **124***a* in the first implanted shape can correspond to the inversion **124** adjacent to the inner segment **146** in the predetermined shape, and an inner braid segment **146***a* suspending the detachment feature **150** in the first implanted shape can correspond to the inner segment **146** in the predetermined shape. In the first implanted shape, the sack **144***a* can have a neck opening **126***a* corresponding to the neck opening **126** in the predetermined shape.

As illustrated in FIG. **1**C, when in the second implanted shape, the braid **110** can have an outer layer **142***b* contacting the aneurysm's wall **14***b*, a proximal inversion **122***b* positioned at the aneurysm's neck **16***b*, a middle layer **144***b* extending within the outer layer **142***b* and pressing against the outer layer **142***b*, a distal inversion **124***b* positioned near the open end **114** of the braid **110**, and an inner layer **146***b* extending within the middle layer **144***b* and pressing against the middle layer **144***b*. In the second implanted shape, the detachment feature **150** and pinched end **112** of the braid **110** can be positioned at the aneurysm neck **16***b*, near the proximal inversion **122***b*.

As illustrated in FIGS. **1**A and **1**C, the tubular braid **110** in the second implanted shape can be radially compressed compared to the predetermined shape, and the middle segment **144** of the predetermined shape can be folded so that the height of the tubular braid **110** is compressed in the second implanted shape compared to the predetermined shape. Alternatively, when implanted in the second implanted shape in aneurysms having a diameter that is significantly smaller than the aneurysm's height, the second implanted shape can be radially compressed compared to the predetermined shape and the height of the braid in the second implanted shape can be greater than the height of the braid in the predetermined shape.

The outer layer **142***b* in the second implanted shape can correspond to the outer layer **142** in the predetermined shape, the proximal inversion **122***b* in the second implanted shape can correspond to the inversion **122** adjacent to the outer layer **142** in the predetermined shape, the middle layer **144***b* and inner layer **146***b* in the second implanted shape can correspond to the middle segment **144** in the predetermined shape, the distal inversion **124***b* in the second implanted shape can correspond to a bend **134** in the middle segment **144** in the predetermined shape, and a portion of the braid **110** near the detachment feature **150** forming the inner layer **146***b* in the second implanted shape can correspond to the inner segment **146** in the predetermined shape.

FIGS. **2**A through **2**H are illustrations of an example implant **100** having a braid **110** expanding to a predetermined shape as the braid **110** exits a microcatheter **600**. The implant **100** has a predetermined shape similar to as illustrated in FIG. **1**A. As illustrated in FIG. **2**A, the braid **110** can be shaped to a delivery shape that is extended to a single layer of tubular braid having a compressed circumference/diameter sized to be delivered through the microcatheter **600** and a length L. The illustrated implant **100** has a length L of between about 22 mm and about 25 mm. As will be appreciated and understood by a person of ordinary skill in the art, the length L of a specific braid **110** can be tailored based on the size and shape of the aneurysm being treated.

During delivery through the microcatheter **600**, the detachment feature **150** can be attached to a delivery system at a proximal end of the implant **100**, the pinched end **112** can be positioned near the proximal end of the implant **100**, and the open end **114** can define the distal end of the implant **100**. Collapsing the braid **110** to a single layer tube can result in a braid **110** that has a sufficiently small diameter and a sufficiently short length L to mitigate effects of friction force on the braid **110** when it is delivered through the microcatheter, allowing the braid **110** to be delivered unsheathed in some applications.

As illustrated in FIG. **2**B, the open end **114** can be positioned to exit the microcatheter **600** before any other portion of the braid **110** exits the microcatheter. The open end **114** can expand as it exits the microcatheter **600**. If the open end **114** is unconstrained by an aneurysm as illustrated, the open end can expand to its circumference in the predetermined shape.

As illustrated in FIG. **2**C, the distal portion of the braid **110** can continue to expand radially as it exits the microcatheter **600**.

As illustrated in FIG. **2**D, the braid **110** can form the inversion **122** defining the outer segment **142** as the braid **110** is further pushed out of the microcatheter **600**.

As illustrated in FIGS. **2**E through **2**G, the "S" shape of the middle segment **144** can begin to form as the braid **110** is further pushed from the microcatheter **600**.

As illustrated in FIG. **2**H, when all, or nearly all of the braid **110** exits the microcatheter **600**, the braid **110**, not confined by an aneurysm, can expand to a predetermined shape similar to the shape illustrated in FIG. **1**A. In the predetermined shape, the braid **110** of the illustrated implant has a diameter between about 6 mm and about 6.5 mm and a height between about 5 mm and about 5.5 mm.

The ratio of the outermost diameter of the braid **110** in the predetermined shape illustrated in FIG. **2**H to the length of the braid **110** in the delivery shape illustrated in FIG. **2**A is between about 0.3 and about 0.24.

FIGS. **3**A through **3**H are illustrations of the implant **100** illustrated in FIGS. **2**A through **2**H expanding within an aneurysm **10** in two different implanted shapes. The aneurysm **10** has a height of about 6 mm, a diameter of about 6 mm, and a neck diameter of about 4 mm. Comparing the dimensions of the aneurysm **10** to the braid **110** in the predetermined shape illustrated in FIG. **2**H, the braid **110** has a slightly larger diameter and a slightly smaller height, and the interior of the aneurysm **10** is substantially spherical while the outer dimensions of the braid **110** are more cylindrical (see FIGS. **6**A and **6**B for measurement orientation). When the braid **110** of the implant **100** is confined by the aneurysm **10**, the braid **110** is therefore be radially constrained.

As illustrated in FIG. **3**A, the implant **100** can be delivered to the aneurysm **10** through the microcatheter **600**, as described in relation to FIG. **2**A. The open end **114** of the tubular braid **110** can expand within the aneurysm **10** as it exits the microcatheter **600**. The illustrated aneurysm **10** is positioned at a bifurcation including a stem blood vessel **20** and two branch vessels **22***a*, **22***b*, and the microcatheter **600** is illustrated being delivered through the stem blood vessel **20**. It is contemplated that the implant could be delivered to an aneurysm on a sidewall of a blood vessel through a curved microcatheter, and such a procedure is intended to be embraced by the scope of the present disclosure.

As illustrated in FIG. **3**B, as the braid **110** is further pushed distally from the microcatheter **600**, the braid **110** can expand to appose the aneurysm wall **14** and conform to the aneurysm neck **16**. The aneurysm **10** being treated can have a diameter that is less than the outer diameter of the tubular braid **110** in the predetermined shape so that the braid **110** tends to expand outwardly, providing a force against the aneurysm wall **14**, and sealing around the perimeter of the aneurysm neck **16**. The implant **100** can be particularly suitable for treating a wide neck aneurysm such as commonly occur at bifurcations because the radial force provided by the braid **110** against the aneurysm wall **14** and perimeter of the neck **16** can be sufficient to both anchor the implant **100** in a wide neck aneurysm and seal the neck **16** of the aneurysm **10**.

As illustrated in FIG. **3**C, as the braid **110** is further pushed distally from the microcatheter **600**, the proximal inversion **122***a* can be formed.

As illustrated in FIG. **3**D, the microcatheter **600** can be manipulated to place the proximal inversion **122***a* at the aneurysm neck **16**. The proximal inversion **122***a* can be placed on a proximal side of a plane defining a boundary **18** (See FIG. **6**B) between the aneurysm **10** and the branch vessels **22***a*, **22***b*. In some applications it can be advantageous to place the proximal inversion **122***a* far enough in the proximal direction from the plane **18** so that the outer layer **142***a* of the braid **110** seals around the outer perimeter of the aneurysm neck **16**, but not so far proximally that the implant **100** becomes an obstruction to the blood vessels **22***a*, **22***b*, **20**.

As illustrated in FIG. **3**E, the braid **110** can expand within the aneurysm sac **12** and extend to appose an inner surface of the outer layer **142***a* of the braid **110**. The apposition to the outer layer **142***a* can provide additional force to anchor the outer layer **142***a* to the aneurysm wall **14**.

As illustrated in FIG. **3**F, the aneurysm **10** has a height that can accommodate the tubular braid **110** in the first implanted shape similar to that illustrated in FIG. **1**B. Because the braid **110** is radially constrained and has a more cylindrical shape compared to the substantially spherical shape of the aneurysm, the braid **110** can extend beyond the height of the predetermined shape to accommodate aneurysms taller than the predetermined shape. In the illustration, the tubular braid **110** of the implant **100** in the predetermined shape has a height between about 0.5 mm and 1 mm less than the height of the aneurysm, or in other words, the implant has extended between about 10% and about 20% in height in the first implanted shape compared to the predetermined shape.

The braid can be pulled proximally as illustrated in FIG. **3**G to form a second implanted shape as illustrated in FIG. **3**H that is similar to the second implanted shape illustrated in FIG. **1**C, but different in that the aneurysm **10***b* illustrated in FIG. **1**C is smaller (proportionally compared to the braid **110**) than the mock aneurysm **10** illustrated in FIG. **3**H. Before the implant **100** is released from the delivery system, the implant **100** can be partially or fully retracted into the microcatheter **600** and repositioned in either of the first implanted shape or the second implanted shape. Additionally, or alternatively, the microcatheter **600** can be moved distally to move the braid **110** from the second implanted shape illustrated in FIG. **3**H to the first implanted shape illustrated in FIG. **3**F. In some applications, while positioning the implant **100**, a physician can choose whether the first implanted shape or the second implanted shape is more suitable for the anatomy of the aneurysm and treatment site. For treatments involving aneurysms and implants shaped similar to the aneurysm **10** and implant **100** illustrated in FIGS. **3**A through **3**H, it can be more advantageous to shape the braid **110** in the first implanted shape as illustrated in FIG. **3**F (rather than the second implanted shape illustrated in FIG. **3**G) because the first implanted shape in this example implementation provides a larger surface area of the braid **110** in contact with the aneurysm wall **14**.

FIGS. **4**A and **4**B are illustrations of the braid **110** of the example implant illustrated in FIGS. **2**A through **2**H and **3**A through **3**H showing the tubular braid **110** expanded within tubes to determine a range of aneurysm diameters and aneurysm heights that an implant **100** having the dimensions of the example implant **100** would be suitable for treating. FIG. **4**A illustrates the braid **110** in a tube having a 5 mm diameter. The braid **110** is in the first implanted shape and has a height of about 8 mm. The braid **110** is therefore radially constrained from its predetermined shape by between about 1 mm and 1.5 mm in diameter, or between about 17% and 23%, and expanded vertically in height by between about 2.5 mm and 3 mm, or between about 45% and 60%.

FIG. **4**B illustrates the braid **110** in a tube having a 4 mm diameter. The braid **110** is in the second implanted shape and has a height of about 6 mm. The braid is therefore radially constrained from its predetermined shape by between about 2 mm and 2.5 mm in diameter, or between about 33% and 38%, and expanded vertically between about 0.5 mm and 1 mm, or between about 10% and 20%.

Implants having a predetermined shape and dimensions as illustrated and described in relation to FIG. **2**H can therefore be suitable for treating aneurysms having a diameter between and including about 4 mm and about 5 mm and a height between and including about 6 mm and about 8 mm. As illustrated in FIG. **3**F, the implant can also be suitable for treating an aneurysm having a diameter of 6 mm and a height of 6 mm. As will be appreciated and understood by a person of ordinary skill in the art, the dimensions of the tubular braid in the predetermined shape can be tailored to treat aneurysms within a range of sizes not specifically outlined herein according to the principles described herein. It is contemplated that a collection of implants so shaped can be made available to physicians, and a physician can choose a suitable implant from the collection based on aneurysm height, diameter, neck diameter, and/or other anatomical features.

A collection of implants, each having a uniquely shaped tubular braid can be created to provide a catalogue of implants for treating aneurysms ranging in diameter and height. The catalogue can include implants suitable for treating aneurysms ranging from 3 mm to 15 mm in diameter and ranging from 3 mm to 15 mm in height, or in another example, ranging from 3 to 11 mm in diameter and 3 to 7 mm in height. As will be appreciated and understood by a person of ordinary skill in the art, some aneurysm dimensions are extremely rare, and the catalog need not include implants for treating aneurysms having a large height: diameter ratio or a large diameter:height ratio.

Each implant in the collection can be suitable for treating aneurysms with a sub range of diameters and a sub-range of heights. An example catalogue can include a listing of implants for treating aneurysms of one or more of, but not limited to, the following size sub ranges (diameter range in mm, height range in mm): (3-5, 3-5), (6-8, 4-5), and (9-11, 5-7).

In some examples, each size sub range can be treated by a single implant having a tubular braid uniquely sized and shaped to be suitable for treating aneurysms within that sub range. In some examples, the sub ranges in the catalogue can be represented by implants each having a tubular braid with a delivery length (length when the braid is collapsed for delivery through a microcatheter) that is about 10 mm, about 40 mm, and/or including a length in between.

As will be appreciated and understood by a person of ordinary skill in the art, aneurysm height and diameter are measured with some margin of error. To that end, the size sub range included in the catalogue for a given implant can represent a portion of aneurysm sizes that can be treated with the implant and the implant can treat aneurysms outside of the listed sub range. For instance, an implant listed for treating aneurysms having heights between height a and height b and diameter range between diameter x and diameter y can be suitable for treating aneurysms slightly taller than the maximum listed height b if the diameter of the aneurysm is near the lower limit of the range (about diameter x), the implant can be suitable for treating diameters slightly larger than diameter y if the height of the aneurysm is near the lower limit of the height range (about height a).

FIGS. **5**A through **5**D are illustrations of the example implant **100** as illustrated in FIGS. **1**A through **1**C implanted in either the first implanted shape or the second implanted shape in aneurysms ranging in size. FIG. **5**A illustrates a large aneurysm **10***a*, FIGS. **5**B and **5**C illustrate a medium aneurysm **10***c*, and FIG. **5**D illustrates a small aneurysm **10***b*. The implant **100** is advantageously implanted in an aneurysm **10***a*, **10***b*, **10***c* having a diameter about equal to or smaller than the diameter of the braid **110** in the predetermined shape so that the braid **110** provides an outward force F against the aneurysm wall **14** when implanted. The braid **110** can have inner layers that press against one or more outer layers, contributing to the force F.

As illustrated in FIG. **5**A, the maximum size of an aneurysm **10***a* that the implant **100** can be suitable for treating can be determined by the dimensions that the braid **110** can take in the first implanted shape. The pinched end **112** and detachment feature **150** can be positioned near a distal portion **15***a* of the aneurysm wall **14***a* as similarly illustrated in FIG. **1**B.

As illustrated in FIG. **5**B, the implant **100** can also be suitable for treating a medium sized aneurysm **10***c* that is smaller than the aneurysm **10***a* illustrated in FIG. **5**A in the first implanted shape. To fit within the medium aneurysm **10***c* in the first implanted shape, the pinched end **112** and detachment feature **150** can be positioned away from the distal portion **15***c* of the aneurysm wall compared to the position of the pinched end **112** and detachment feature **150** in the large aneurysm **10***a*. In the predetermined shape (see FIG. **1**A), the middle segment **144** can include a bend **134** to stabilize the tubular braid **110** in the first implanted shape in the medium aneurysm **10***c* as illustrated in FIG. **5**B.

As illustrated in FIG. **5**C, the implant **100** can also be suitable for treating the medium sized aneurysm **10***c* in the second implanted shape. The middle segment **144** of the braid in the predetermined shape (see FIG. **1**A) can be folded to form a middle layer **144***b* and an inner layer **146***b* similar to as described in relation to FIG. **1**C. In some applications, either implanted shape could be effective for treating the aneurysm **10***c*, and a physician can select a preferred shape during treatment. For instance, a physician can decide to use the first implanted shape (FIG. **5**B) to elongate the implant so that the proximal fold **122***a* can be placed proximally outside of the aneurysm neck, or the physician can decide to use the second implanted shape (FIG. **5**C) to provide more layers of braid at the aneurysm neck to occlude the neck opening **16***c*.

As illustrated in FIG. **5**D, the minimum size of aneurysm **10***b* that the implant **100** can be suitable for treating can be determined by the dimensions that the braid **110** can take in the second implanted shape. The open end **114** and/or the distal fold **124***b* can be collapsed near a distal portion **15***b* of the aneurysm wall in the second implanted shape.

FIG. **6**A is an illustration of height HI and diameter D**1**, D**2** measurements of an example implant **100** in a predetermined shape. In the predetermined shape, the braid **110** of the example implant **100** can be substantially radially symmetrical about vertical axis y, and therefore can have substantially circular concentric cross-sections each describable by its diameter. FIG. **6**A highlights the height HI of the implant **100** in a predetermined shape measured between the inversions **122**, **124**, the outer diameter D**1** of the outer segment **142**, which corresponds to the diameter of the open end **114**, and the outer diameter D**2** of the middle segment D**2**. Although FIG. **6**A illustrates only one example predetermined shape, it should be understood that the height and

diameter of example implants described herein **100**, **200**, **300**, **400** and portions thereof can be measured similarly to as illustrated in FIG. **6**A.

FIG. **6**B is an illustration of height HA, sac diameter DA, and neck diameter DN measurements of an aneurysm **10**. The location of the plane **18** defining a boundary between the aneurysm **10** and blood vessels is also illustrated.

FIG. **7**A is an illustration of an example implant **200** having a tubular braid **210** in an alternative predetermined shape. FIG. **7**B is an illustration of the example implant **200** in an aneurysm **10** with the tubular braid **210** in an implanted shape. The tubular braid **210** can have an open end **214** and a pinched end **212**. The implant **200** can include a detachment feature **150** attached to the braid **210** at the pinched end **212**. The braid **210** can be formed in the predetermined shape, collapsed for delivery through a microcatheter, attached to a delivery system at the detachment feature **150**, and implanted in the implanted shape.

As illustrated in FIG. **7**A, when in the predetermined shape, the tubular braid **210** can include two inversions **222**, **224**, dividing the braid **210** into three segments **242**, **244**, **248**. In the predetermined shape, the braid **210** can have an outer segment **242** extending from the open end **214** of the braid **210** to one of the inversions **222**, an inner segment **248** extending from the pinched end **212** of the braid **210** to the other of the inversions **224**, and a middle segment **244** extending between the two inversions **222**, **224**. When in the predetermined shape, the tubular braid **210** can be substantially radially symmetrical about a central vertical axis y (see FIG. **6**A). FIG. **7**A illustrates a profile of each segment **242**, **244**, **248**.

Comparing the predetermined shape of the braid **210** illustrated in FIG. **7**A to that of the braid **110** illustrated in FIG. **1**A, the outer segments **142**, **242** and middle segments **144**, **244** are respectively similar to each other, and the inner segment **248** of the braid **210** illustrated in FIG. **7**A is longer than the inner segment **146** of the braid **110** illustrated in FIG. **1**A. The pinched end **212** of the braid **210** in FIG. **7**A is positioned near the inversion **222** adjacent the outer segment **242** rather than near the inversion **124** near the inner segment **146** as illustrated in FIG. **1**A. The elongated inner segment **248** illustrated in FIG. **7**A can be positioned to help the implant **200** resist compaction when implanted as illustrated in FIG. **7**B.

The tubular braid **210** illustrated in FIG. **7**A can be formed into the predetermined shape similar to as described in relation to FIG. **1**A with some differences. The middle segment **244** need not have bends **132**, **134** positioned facilitate the movement of the braid **210** into a second implanted shape. The inner segment **248** as illustrated in FIG. **7**A can be made longer than that illustrated in FIG. **1**A. The inner segment **248** can be shaped to have a length that is optimized to reduce the likelihood that the implant **200** can become compacted when implanted.

An implant **200** having a braid **210** having a predetermined shape as illustrated in FIG. **7**A can have outer dimensions in the predetermined shape including an outer diameter and height similar to as illustrated and described in relation to FIG. **2**H. The inner segment **248** of the braid **210** illustrated in FIG. **7**A can have a height that is approximately equal to the height of the braid **210** in the predetermined shape.

The braid **210** can be elongated to a single layer tubular braid in a delivery shape that is sized to traverse a microcatheter. The length of the braid **210** in the delivery shape can be measured from the open end **214** to the pinched end **212**. A braid **210** having a predetermined shape as illustrated in FIG. **7**A and outer dimensions as illustrated and described in relation to FIG. **2**H can have a length in the delivery shape that is longer compared to the length of the braid **110** illustrated in FIG. **2**A. The length of the braid **210** illustrated in FIG. **7**A when in the delivery shape can be longer than a braid **110** having a predetermined shape as illustrated in FIG. **1**A by about the height of the braid **110**, **210** in the predetermined shape. In other words, an implant **200** having a braid **210** with a predetermined shape as illustrated in FIG. **7**A can have an outer diameter between about 6 mm and about 6.5 mm and a height between about 5 mm and 5.5 mm when in the predetermined shape and can be elongated to a single layer tube having a circumference collapsed to fit within a microcatheter and a length measuring between about 27 mm and 30 mm. The ratio of outermost diameter in the predetermined shape to length in the delivery shape can be between about 0.24 and about 0.2.

As illustrated in FIG. **7**B, when in the implanted shape, the braid **210** can have an outer layer **242***a* contacting the aneurysm's wall **14**, a sack **244***a* nested within the outer layer **242***a*, a proximal inversion **222***a* positioned at the aneurysm's neck **16**, and a distal inversion **224***a* positioned near a distal portion **15** of the aneurysm wall **14**. The detachment feature **150** and pinched end **212** of the braid **210** can be positioned near the aneurysm neck **16**, near the proximal inversion **222***a*. The detachment feature **150** and pinched end **212** can be positioned to reduce the likelihood that the implant **200** becomes impacted.

FIG. **8**A is an illustration of an example implant **300** having a tubular braid **310** in another alternative predetermined shape. FIG. **8**B is an illustration of the example implant **300** when the tubular braid **310** in an implanted shape. The tubular braid **310** can have an open end **314** and a pinched end **312**, and a detachment feature **150** can be attached to the braid **310** at the pinched end **312**. The braid **310** can be formed in the predetermined shape, collapsed for delivery through a microcatheter, attached to a delivery system at the detachment feature **150**, and implanted in the implanted shape.

As illustrated in FIG. **8**A, when in the predetermined shape, the tubular braid **310** can include two inversions **322**, **324**, dividing the braid **310** into three segments **342**, **344**, **346**. In the predetermined shape, the braid **310** can have an outer segment **342** extending from the open end **314** of the braid **310** to one of the inversions **322**, an inner segment **346** extending from the pinched end **312** of the braid **310** to the other of the inversions **324**, and a middle segment **344** extending between the two inversions **322**, **324**. When in the predetermined shape, the tubular braid **310** can be substantially radially symmetrical about a central vertical axis. FIG. **8**A illustrates a profile of each segment **342**, **344**, **346**.

Comparing the predetermined shape of the braid **310** illustrated in FIG. **8**A to that of the braid **110** illustrated in FIG. **1**A, the outer segments **142**, **342** and inner segments **146**, **346** are respectively similar to each other, and the middle segment **344** of the braid **310** illustrated in FIG. **8**A has an undulating pattern rather than the "S" shape of the middle segment **144** of the braid **110** illustrated in FIG. **1**A. The undulating middle segment **344** can be radially symmetrical to form a honeycomb shape. When implanted, the middle segment **344** in the undulating pattern can provide a force pattern pressing outwardly to anchor the implant **300** within an aneurysm that is different from a force pattern that could be provided by the middle segment **144** having the "S" shape illustrated in FIG. **1**A. The pinched end **312** of the braid **310** in FIG. **8**A can be positioned near the inversion **324** adjacent the inner segment **346** as illustrated. Alterna-

tively, the inner segment **346** can be shaped to extend to the inversion **322** adjacent the outer segment **342** to provide a compaction resistant column.

The tubular braid **310** illustrated in FIG. **8**A can be formed into the predetermined shape similar to as described in relation to FIG. **1**A with some differences. The middle segment **344** can be formed to have an undulating pattern rather than an "S" shaped pattern. The middle segment **344** need not have bends positioned facilitate the movement of the braid **310** into a second implanted shape.

As illustrated in FIG. **8**B, when in the implanted shape, the braid **310** can have an outer layer **342***a* shaped to contact an aneurysm wall, compressed extensions of an undulating middle layer **344***a* nested within the outer layer **342***a*, a proximal inversion **322***a* positioned to be placed an aneurysm neck, and a distal inversion **324***a* positioned to be placed near a distal portion of the aneurysm wall. The detachment feature **150** and pinched end **312** of the braid **310** can be positioned within the aneurysm sac, either near the distal inversion **324***a* as illustrated, near the proximal inversion **322***a*, or at a position in between. The detachment feature **150** and pinched end **312** can be positioned to reduce the likelihood that the implant **300** becomes impacted.

FIG. **9**A is an illustration of an example implant **400** having a tubular braid **410** in another alternative predetermined shape. FIG. **9**B is an illustration of the example implant **400** illustrating the tubular braid **410** in an implanted shape. The tubular braid **410** can have an open end **414** and a pinched end **412**. A detachment feature **150** can be attached to the braid **410** at the pinched end **412**. The implant **400** can be formed in the predetermined shape, collapsed for delivery through a microcatheter, attached to a delivery system at the detachment feature **150**, and implanted in the implanted shape.

As illustrated in FIG. **9**A, when in the predetermined shape, the tubular braid **410** can include two inversions **422**, **424**, dividing the braid **410** into three segments **442**, **444**, **446**. In the predetermined shape, the braid **410** can have an outer segment **442** extending from the open end **414** of the braid **410** to one of the inversions **422**, an inner segment **446** extending from the pinched end **412** of the braid **410** to the other of the inversions **424**, and a middle segment **444** extending between the two inversions **422**, **424**. When in the predetermined shape, the tubular braid **410** can be substantially radially symmetrical about a central vertical axis y (see FIG. **6**A). FIG. **9**A illustrates a profile of each segment **442**, **444**, **446**.

Comparing the predetermined shape of the braid **410** illustrated in FIG. **9**A to that of the braid **110** illustrated in FIG. **1**A, the outer segments **142**, **442** can be similar to each other, the middle segment **444** of the braid **410** illustrated in FIG. **9**A can have a less pronounced "S" shape compared to the "S" shaped middle segment **144** illustrated in FIG. **1**A, and the inner segment **446** can be conical or "V" shaped in profile with the pinch end **412** positioned near the inversion **422** adjacent the outer layer **442** rather than near the inversion **142** adjacent the inner layer **146** as illustrated in FIG. **1**A. When implanted, the inner segment **446** can reshape to form a compaction resistant column.

The tubular braid **410** illustrated in FIG. **9**A can be formed into the predetermined shape similar to as described in relation to FIG. **1**A with some differences. The middle segment **444** illustrated in FIG. **9**A can be formed to have a less pronounced "S" shape pattern compared to the "S" shaped pattern **144** illustrated in FIG. **1**A. The middle segment **444** need not have bends positioned facilitate the movement of the braid **410** into a second implanted shape. The inner segment **446** can have a longer length as illustrated in FIG. **9**A compared to the inner segment **146** illustrated in FIG. **1**A. The inversion **424** adjacent the inner segment **446** can have a more acute curvature as illustrated in FIG. **9**A compared to the corresponding inversion **124** illustrated in FIG. **1**A.

As illustrated in FIG. **9**B, when in the implanted shape, the braid **410** can have an outer layer **442***a* shaped to contact an aneurysm wall, a tulip or heart shaped sack **444***a* nested within the outer layer **442***a*, a proximal inversion **422***a* positioned to be placed at an aneurysm neck, a distal inversion **424***a* positioned to be placed near a distal portion of the aneurysm wall, and a compaction resistant column **446***a* extending within the sack **444***a*. The detachment feature **150** and pinched end **412** of the braid **410** can be positioned within the sack **444***a* near the proximal inversion **422***a*. The detachment feature **150** and pinched end **412** can be positioned to reduce the likelihood that the implant **400** becomes impacted.

FIG. **10** is an illustration of an example implant **400** having a tubular braid **410** in a predetermined shape similar to as illustrated in FIG. **9**A.

FIGS. **11**A through **11**E are illustrations of the example implant **400** illustrated in FIG. **10** showing the tubular braid **410** expanding to the implanted shape within a mock aneurysm **10** similar to as illustrated in FIG. **9**B. As illustrated in FIG. **11**A, the open end **414** can exit the microcatheter first and expand within the aneurysm **10**. As illustrated in FIG. **11**B, a distal portion of the braid **410** corresponding to the outer layer **442** in the predetermined shape can expand to appose the aneurysm wall **14** forming the outer later **442***a* in the implanted shape. As illustrated in FIG. **11**C, the braid **410** can begin to invert as the braid **410** is further pushed distally from the microcatheter **600**. As illustrated in FIG. **11**D, the proximal inversion **422***a* can be placed at the aneurysm neck **16** as the tulip shaped sack **444***a* expands within the outer layer **442***a*. As illustrated in FIG. **11**E, the braid **410** can be shaped in the implanted shape within the aneurysm **10** similar to as illustrated in FIG. **9**B.

The tubular braid **110**, **210**, **310**, **410** of the example implants **100**, **200**, **300**, **400** can include memory shape material that can be heat set to a predetermined shape, can be deformed for delivery through a catheter, and can self-expand to an implanted shape that is based on the predetermined shape and confined by the anatomy of the aneurysm in which it is implanted.

The example implants **100**, **200**, **300**, **400** described herein can rely on a radial outward force to anchor the implant within the sac of an aneurysm. To this end, the braid **110**, **210**, **310**, **410** can be shaped to a predetermined shape having a diameter that is greater than its height so that the braid is radially constricted when implanted in an aneurysm. The ratio of diameter to height of the braid **110**, **210**, **310**, **410** in a respective predetermined shape can be within the range of 2:1 to 1:3 to treat aneurysms of many known sizes and shapes.

The descriptions contained herein are examples of embodiments of the invention and are not intended in any way to limit the scope of the invention. As described herein, the invention contemplates many variations and modifications of the implant, including alternative materials, alternative geometries, alternative detachment features, alternative delivery systems, alternative means for forming a braid into a predetermined shape, alternative treatment methods, etc. These modifications would be apparent to those having

ordinary skill in the art to which this invention relates and are intended to be within the scope of the claims which follow.

What is claimed is:

1. An implant comprising:

a tubular braid comprising an open end, a pinched end, and a predetermined shape;

wherein, in the predetermined shape, the tubular braid comprises:

a first segment extending from the open end to a first inversion,

a second segment encircled by the open end such that the second segment is only partially surrounded by the first segment and extending from the first inversion to a second inversion, and

a third segment surrounded by the second segment and extending from the second inversion to the pinched end.

2. The implant of claim **1**,

wherein, when the tubular braid is in the predetermined shape, the open end comprises a diameter approximately equal to a maximum diameter of the second segment.

3. The implant of claim **1**,

wherein the tubular braid is stable in a first implanted shape based on the predetermined shape when constrained by a first substantially spherical cavity and the tubular braid is stable in a second implanted shape based on the predetermined shape when constrained by a second substantially spherical cavity;

wherein, in each of the first implanted shape and the second implanted shape, the tubular braid comprises an outer layer corresponding to the first segment of the predetermined shape and a proximal inversion corresponding to the first inversion of the predetermined shape,

wherein, in the first implanted shape, the outer layer is positioned to contact a cavity wall of the first substantially spherical cavity, and the proximal inversion is positioned to be placed approximate an entrance of the first substantially spherical cavity;

wherein, in the first implanted shape, the tubular braid comprises a sack corresponding to the second segment of the predetermined shape, and the sack is positioned to appose a portion of an cavity wall of the first substantially spherical cavity and the sack apposes the outer layer;

wherein, in the second implanted shape, the outer layer is positioned to contact a cavity wall of the second substantially spherical cavity, and the proximal inversion is positioned to be placed approximate an entrance of the second substantially spherical cavity; and

wherein, in the second implanted shape, the tubular braid comprises a middle layer apposing the outer layer and an inner layer apposing the middle layer, the middle layer and the inner layer correspond to the second segment of the predetermined shape, and a fold separates the middle layer and the inner layer.

4. The implant of claim **3**,

wherein, in the predetermined shape, the tubular braid comprises a bend positioned in the second segment; and

wherein, when the tubular braid is in the second implanted shape, the fold separating the middle layer and the inner layer corresponds to the bend in the second segment of the predetermined shape.

5. The implant of claim **3**,

wherein, when the tubular braid is in the first implanted shape, the open end encircles the sack; and

wherein, when the tubular braid is in the second implanted shape, the open end encircles the fold.

6. The implant of claim **1**,

wherein, the tubular braid further comprises an implanted shape; and

wherein in the implanted shape, the tubular braid comprises an outer layer positioned to appose an aneurysm wall, an inner sack positioned to appose a portion of an aneurysm wall and to appose the outer layer, a proximal inversion positioned to be placed approximate an aneurysm neck, a distal inversion positioned to be placed approximate a distal portion of the aneurysm wall, and a compaction resistant post extending centrally within the inner sack and along a majority of a length between the distal inversion and the proximal inversion; and

wherein, the outer layer in the implanted shape corresponds to the first segment in the predetermined shape, the inner sack in the implanted shape corresponds to the second segment in the predetermined shape, the proximal inversion in the implanted shape corresponds to the first inversion in the predetermined shape, the distal inversion in the implanted shape corresponds to the second inversion in the predetermined shape, and the compaction resistant post in the implanted shape corresponds to the third segment in the predetermined shape.

7. The implant of claim **1**,

wherein the implant is configured to treat a first aneurysm comprising a first diameter measuring about 4 mm and a first height measuring about 6 mm, a second aneurysm comprising a second diameter measuring about 5 mm and a second height measuring about 8 mm, and a third aneurysm comprising a third diameter measuring about 6 mm and a third height measuring about 6 mm.

8. The implant of claim **1**,

wherein the implant is configured to treat a plurality of aneurysms within a continuum of aneurysm sizes, the continuum bounded by and including diameters between about 4 mm and about 5 mm and heights between about 6 mm and about 8 mm.

9. An implant comprising:

a tubular braid comprising an open end, a pinched end, and a predetermined shape;

wherein, in the predetermined shape, the tubular braid comprises a first segment extending from the open end to a first inversion, a second segment encircled by the open end and extending from the first inversion to a second inversion, and a third segment surrounded by the second segment and extending from the second inversion to the pinched end,

wherein the tubular braid is stable in a first implanted shape based on the predetermined shape when constrained by a first substantially spherical cavity and the tubular braid is stable in a second implanted shape based on the predetermined shape when constrained by a second substantially spherical cavity,

wherein, in each of the first implanted shape and the second implanted shape, the tubular braid comprises a proximal inversion corresponding to the first inversion of the predetermined shape,

wherein, when the tubular braid is in the first implanted shape, the pinched end is suspended within a sack corresponding to the second segment in the predetermined shape; and

wherein, when the tubular braid is in the second implanted shape, the pinched end is encircled by the proximal inversion and the tubular braid comprises a middle layer, an inner layer apposing the middle layer, and a fold separating the middle layer and inner layer, the middle layer, the inner layer, and the fold corresponding to the second segment of the predetermined shape.

* * * * *